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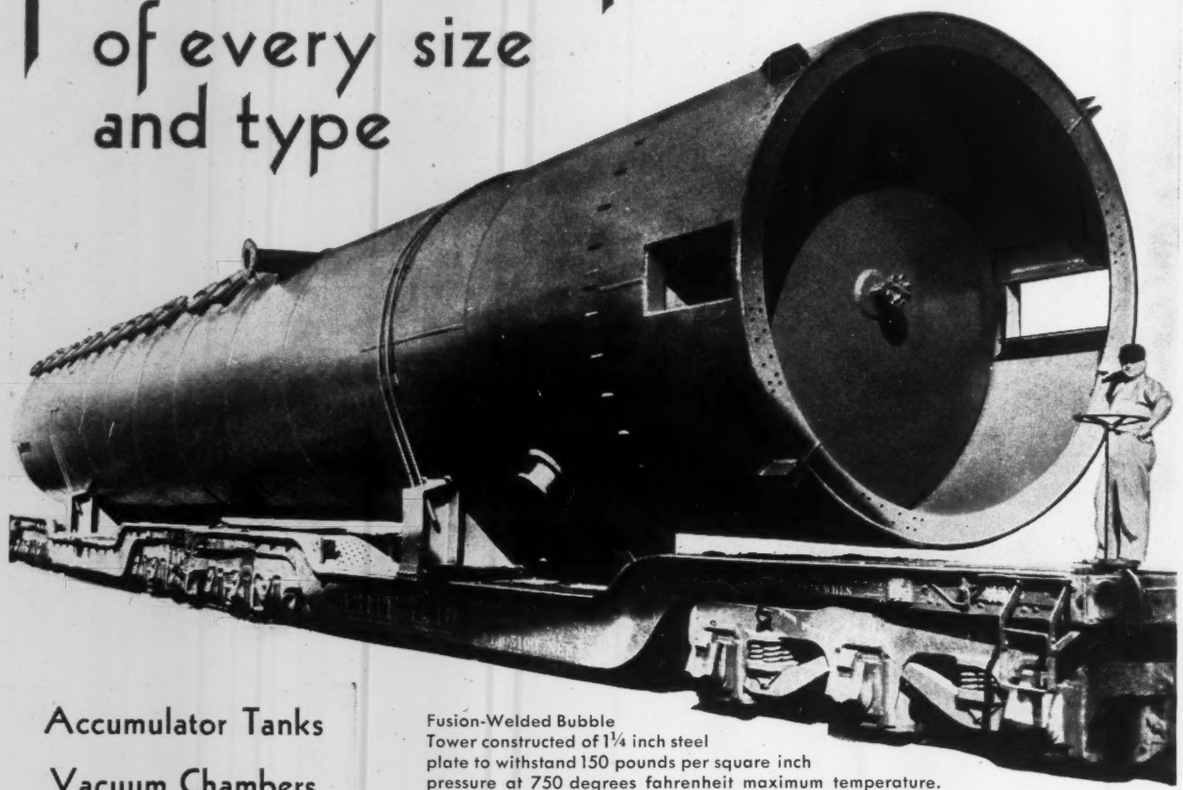
MECHANICAL ENGINEERING

1933

Fusion-Welded Pressure Vessels of every size and type



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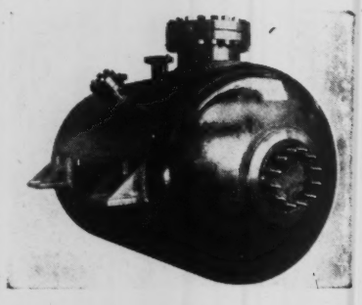

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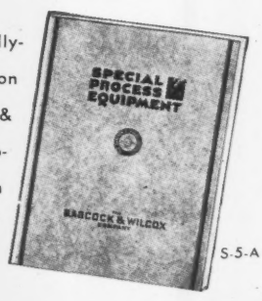

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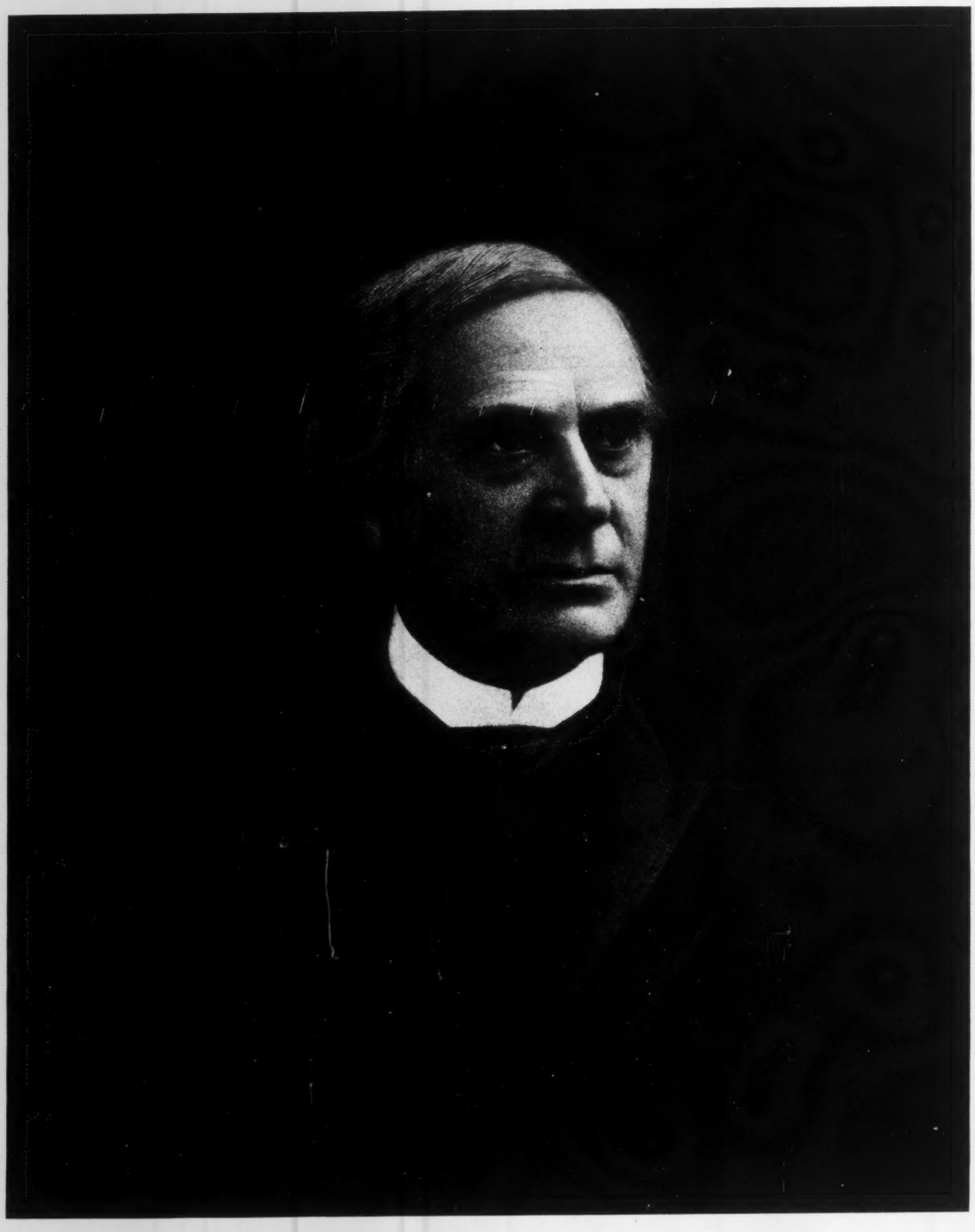


Yours truly

Geo H. Corliss.

GEORGE H. CORLISS:

One of the Leading Pioneers in the Development of Power Generation From Watt to the Present Day

By J. A. HALL[1] and G. W. RICHARDSON[2]

THE name Corliss probably means little to the young mechanical engineer except that it was applied to a type of steam engine commonly installed a generation ago when mechanical rather than electrical transmission of power predominated. Yet in 1888, *Engineering*, of London, stated in an obituary notice: "By the death of George Henry Corliss, America has lost the best-known engineer she has ever produced," while the official German report of the Vienna International Exposition (as quoted by Robert H. Thurston),[3] after noting that the principal advances in machinery had been in prime movers, continues: "Principally with reference to stationary engines, a complete change of the construction is to be noted, and we owe this mainly to the influence of the American Corliss." The first Corliss engine to be shown in Europe had been one of the sensations at the Paris Exposition of 1867 and apparently had made an immediate and favorable impression.

Interest in getting accurate information concerning this great American engineer while a few of his associates were still alive has led the Engineering Division of Brown University to collect all possible data on his life and technical achievements. The privately printed "Life and Work of George H. Corliss," prepared under direction of his niece, Mary Corliss, in 1930, gave a good starting point. "The Early History of the Corliss Engine in the United States," a paper written in 1902 by George T. Phillips, who was an engineer for Mr. Corliss during the sixties and seventies, is particularly reliable. The Business Historical Society of Cambridge, Mass., possesses a large number of original documents, and there is a considerable collection at Brown University. Many old records have been furnished by the Franklin Machine Company, present owners of the old Corliss shops. Recollections concerning both the personality and technical work of Corliss have been contributed, among others, by Nathaniel Greene Herreshoff,[4] who was a draftsman and experimental engineer at the Corliss plant for the nine years following his graduation from Massachusetts Institute of Technology in 1869, Frank G. Tallman,[5] assistant shop foreman for eighteen months in 1880–1881, and H. A. Du Villard,[6] personal draftsman for Corliss (1878–1887).

George H. Corliss was born at Easton, N. Y., June 2, 1817, the son of Dr. Hiram Corliss, a surgeon. He received a fairly good common-school education, and, after spending some time at the Castleton (Vermont) Academy, became a storekeeper at Greenwich, N. Y. A few years later his mechanical ability made its first appearance when young Corliss invented a sewing machine for stitching harness leather. The patent, dated December, 1843, or nearly three years before that of Elias Howe, shows an ingenious assembly of needles, fingers, and power-driven awls. The original model is now among the exhibits at the Massachusetts Institute of Technology.

Corliss came to Providence to perfect his model and to get financial backing, which did not materialize. However, the trip did result in a letter from Edward Bancroft, dated February 20, 1844, offering him a job as draftsman at $1.50 a day with Fairbanks, Bancroft & Company, of that city. "For a person who sees the 'why' of a thing as readily as you do," wrote Bancroft, "I should have no fear of your succeeding in a business connected with 'Steam Engines' and other machinery." The invitation was accepted and Corliss came to Providence. His new employers were an established concern, having operated a shop as Fairbanks, Clark & Company as early as 1838.

His advance must have been phenomenal. An advertisement in the *Providence Journal* of February, 1846, lists the new draftsman as one of the firm, then known as Bancroft, Nightingale & Company, while early in 1847 the name was changed to Corliss, Nightingale & Company, with Corliss the head of the organization. Bancroft went to Philadelphia, apparently taking with him William Sellers who also had been in his employ for several years. There they formed the firm of Bancroft & Sellers, later the William Sellers Company.

A memorandum book used by Corliss, Nightingale & Company in the year 1847 gives a good idea of the work done by the concern at that time. Although engines and boilers are most frequently mentioned, there are references to cutting gear teeth, the turning and cutting of "bevel wheels," the building of lathes, planing machines, and spliners, and general machine work. As regards the "bevel wheels," Corliss' second patent, No. 6161, of March, 1849, covered a bevel-gear planing

[1] Professor of Mechanical Engineering, Brown University. Mem. A.S.M.E.

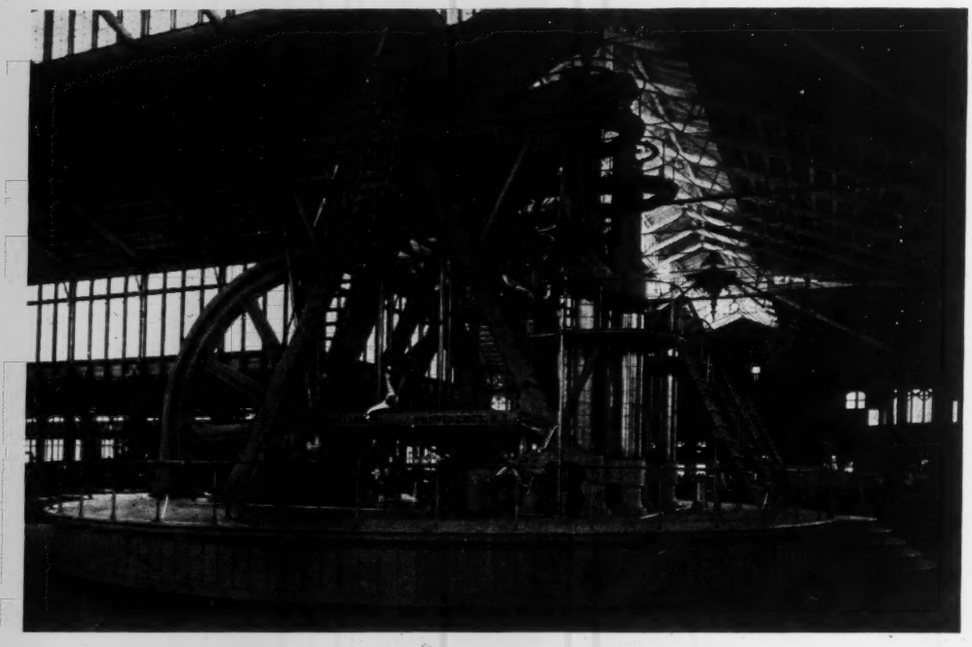
[2] Engineer, Providence, R. I.

[3] "Mechanical Engineering at Vienna, 1873," by Robert H. Thurston, p. 40.

[4] Bristol, R. I., Hon. Mem. A.S.M.E.

[5] Vice-Pres., E. I. du Pont de Nemours & Co., Wilmington, Del., Mem. A.S.M.E.

[6] Pres., Textile Finishing Machinery Co., Providence, R. I. Mem. A.S.M.E.



THE WONDER OF THE CENTENNIAL EXPOSITION, PHILADELPHIA, PA. CORLISS' 1400-HP ENGINE THAT DROVE, BY MEANS OF A SHAFT BENEATH THE FLOOR, ALL OF THE MACHINERY IN MACHINERY HALL IN 1876

machine, in which a carefully made template guided the end of a pivoted bar which carried the tool.

However, the principal products of the shop were steam engines, and it is but natural that the attention of Corliss should be directed toward improvements in this line. In July, 1847, a contract was made with the Providence Dyeing, Bleaching, and Calendering Company for the building of a 260-horsepower beam engine which was the first to embody the new Corliss valve gear. The essential feature of the arrangement was the automatic control of releasing steam valves, permitting full boiler pressure steam to act upon the piston up to the point of cut-off without the use of a throttling governor. Four flat slide valves, one steam and one exhaust for each end of the cylinder, were operated from a rocking wristplate. Detachment of the steam valves occurred at a point determined by the position of the fly-ball governor, their closure being cushioned by air dashpots. Later forms of the engine differed only in details, such as the form of the valves and the arrangement of releasing gear, the basic principles being retained. The abandoning of the throttling governor and the decrease in clearance brought about by the Corliss system caused substantial gains in efficiency, while the regulation by the valve-releasing method was highly satisfactory.

The new "calender engine," started February 17, 1848, was a complete success. The superintendent later stated in court testimony: "The throttle valve regulation (with the old engine) was as bad as it could be. . . . We had some machinery we never allowed to run without an engineer standing at the screw valve to shut the steam off. . . . It (the regulation with the Corliss engine) was as near perfect as I ever expect to get."

After a similar engine, built in 1848 for the Wamsutta Company, of New Bedford, proved successful, Corliss applied for a patent, which was issued under date of March 10, 1849 (No. 6162).

Almost immediately, Corliss, Nightingale & Company were sued for infringement of patents, issued in 1842 and 1845, to Frederick E. Sickels, which covered a releasing gear combined with "puppet" valves and the use of a water dashpot to cushion the closure. The Sickels interests were upheld by Thurston, Greene & Company, of Providence, who acquired the patents in 1852. The plaintiffs showed that a governor-controlled cut-off valve had been used by Maudslay in England, in the twenties, and by Zachariah Allen in Providence, in 1834. Corliss' lawyer pointed out that these earlier engines had employed an auxiliary "expansion valve" outside the steam chest while retaining the ordinary valves and, moreover, that several forms of drop cut-off had been used before 1842, notably by one Hogg, on the S.S. *South America*. Further, Sickels' claim covered only "puppet" valves and said nothing about governor control. The Sickels side never got a satisfactory verdict, and their failure in the Evans and Seagrave case of 1863 practically closed the contest.

In 1855, Noble T. Greene, of Thurston, Greene & Company, patented an arrangement wherein the steam-valve closure was regulated by governor control. Corliss, realizing that the idea was fundamentally the same as his, began suit against the users of the new type of engine. Thus came about the curious circumstance of two firms, in the same city at the same time, each suing the other and all purchasers of the other's product. The Corliss-Greene suits were soon settled when, in 1861, Judge Nelson, of the United States Circuit Court, decided against Wheeler & Wilson, of Bridgeport, Conn., who were using a Greene machine. With this case settled in favor of the plaintiffs, little trouble was found in securing injunctions against all other users.

Corliss always retained the best legal talent, among others, William H. Seward, later Secretary of State under Lincoln. Records show that, exclusive of his personal service, Corliss spent $108,226.80, largely for lawyers' fees. The opponents' costs also must have reached a sizable figure. The suits were bitterly fought

and aroused much feeling. It is, therefore, significant that Robert H. Thurston, first president of The American Society of Mechanical Engineers, when on the Jury of Awards of the Vienna Exposition in 1873, made the recommendation that a diploma of honor be awarded to this opponent of his father's firm because of the excellence of the large number of Corliss-type engines exhibited, although none of these was built by Corliss himself.

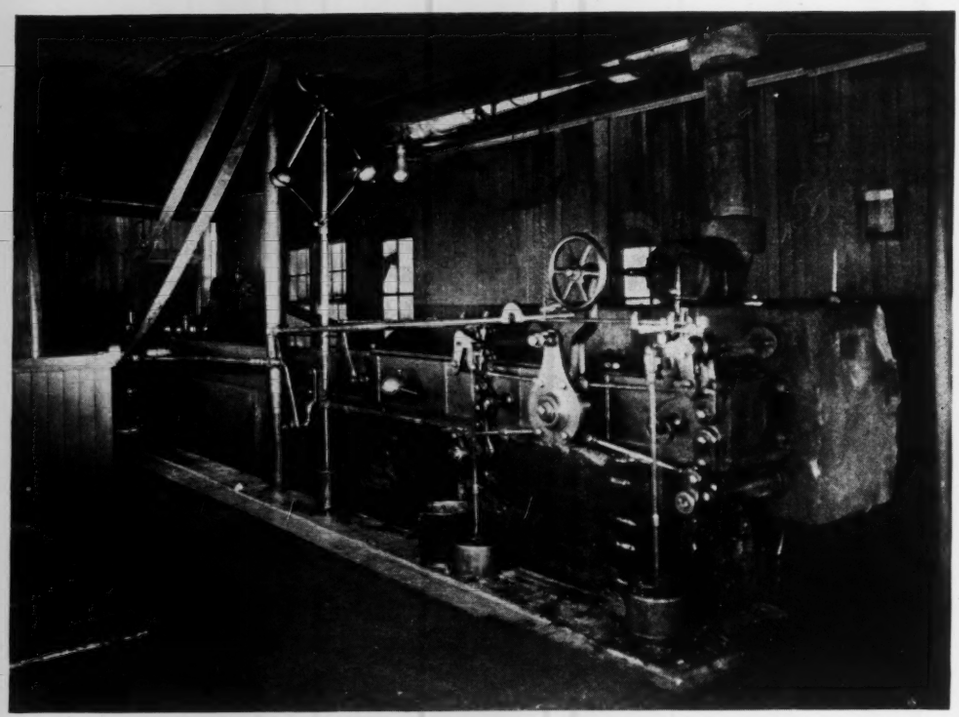
In spite of legal distractions, Corliss apparently found time to introduce his improvements, as more than 300 engines had been installed by 1862. Protection against patent suits was, of course, guaranteed in each case. At first it was hard to convince manufacturers of the great superiority of the Corliss engine. To overcome this reluctance, Corliss began to guarantee efficiencies, some of which were stated in such unusual units as "barrels of flour (produced) per ton of coal." Should the promised saving not be effected, definite forfeits were stated. In 1854, a 200-horsepower engine, requiring nine tons of coal per day at the plant of the Washington Mills, of Gloucester, N. J., was replaced by a Corliss engine for $7100, with a forfeit clause in the contract of $5000 for each ton of coal per day over four tons required to run the mill. Another favorite method was the furnishing of an engine for the value of the coal saved over a period of years. The customer had the alternative of paying list price at installation. In 1855, the James Steam Mill, of Newburyport, for instance, paid $19,734.22 in savings instead of the original offer of $10,500.

From the beginning, Corliss prospered financially. The original capital of the company in 1847 was $36,767.26, of which he supplied $1,097.26, receiving a one-third interest. The profits for the remaining eleven months of that year were $41,498.60, of which Corliss drew out $1,163.66 for living expenses. In 1850, on the withdrawal of the third partner, the firm became Corliss & Nightingale, with the former a half-owner. Most of the profits were put back into the business, and, in 1848, construction was begun on a new plant which, by 1870, had grown into one of the largest and most famous factories in the United States. The capital increased in ten years to $296,323.07, the profits in this period being $301,050.41. In 1857, the firm was reorganized again, becoming the Corliss Steam Engine Company, Nightingale and Corliss still holding equal shares. Finally, in 1863, Nightingale was bought out by his partner. Some idea of Corliss' ability as a Yankee trader is indicated by the fact that the purchase was made at par, although entries in the diary of his brother William, made a few weeks previous, indicate that he was willing to pay $175 or more per share. Only $500 in cash was involved, the rest being part ownership in steamboats and other property outside the plant.

Aside from his returns from the business, Corliss had an income from royalties. He never assigned his patents to the company, the latter paying a fee for each engine built. At one time, for example, the standard rate was $1.50 per square inch of piston area for cylinders less than 24 inches in diameter and $1.12½ for larger sizes. Records published in 1869 in a petition for patent extension show that $332,102.49 had been paid or were due at that date. This amount included fees from other companies licensed by him, and also collections from infringers.

During the early fifties, Corliss did much to improve the appearance and operation of his product. He early abandoned the clumsy "box bed" then used by most builders and developed the girder or "Corliss" type,

MACHINE DESIGNED AND BUILT BY CORLISS FOR PLANING THE BEVEL GEARS USED WITH THE CENTENNIAL ENGINE



THE EAGLE DYE WORKS ENGINE WITH BOX BED, INSTALLED IN 1851 AND STILL RUNNING

where lightness is combined with strength and much foundation work is saved. He also paid much attention to the quality of material used, insisting on the best always. Thus he became convinced that the wrought iron in horseshoes was of a superior grade, due in part to the pounding they had received on the pavements. These, heated to the fusing point in a special furnace, were forged into bars for use in cases where exceptional strength was required, as in long connecting rods. The pile of old horseshoes in the yard is still remembered by some Providence residents. Corliss finish and workmanship became justly celebrated. The *Engineer*, of London, referred to his exhibit at the Paris Exposition (1867) as "a splendid piece of workmanship," while in this country an engine at the Eagle Dye Works, Valley Falls, R. I., installed in 1851, is still its only source of power after 82 years of continuous service.

His inventive faculties were constantly at work, as evidenced by more than 70 patents. These covered not only steam-engine appliances and valve-gear arrangements, but also a variety of pumping-engine designs, steam specialties, boilers, and machine tools. The cylindrical valve, now considered a fundamental part of a Corliss engine, was never patented, though adopted in the early fifties. The long list of changes in valve operating gear need not be detailed, such alterations being concerned with form rather than basic principle. The most important of these was the final substitution of the vacuum dashpot for the earlier weight-and-spring-lever designs, permitting quicker valve closure and higher engine speeds.

In 1851, Corliss first attempted to apply his valve gear to locomotives. Alexander Lyman Holley, Honorary Member in Perpetuity, A.S.M.E., on his graduation from Brown University in 1853, became draftsman and test engineer on this work, and some of his amusing experiences are told in "A Memorial Address."[7] Holley left Corliss & Nightingale in March, 1855, upon the discontinuance of this work. Applications to marine engines also were not pushed to a successful conclusion; and the experimental boats constituted about 90 per cent of the property transferred to Nightingale on his withdrawal.

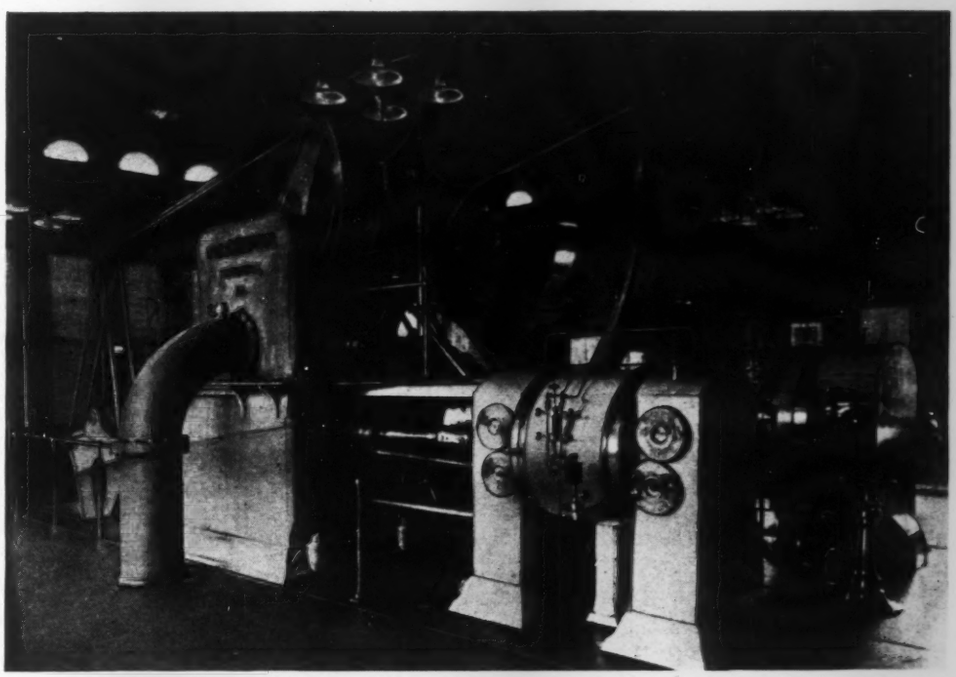
In 1872 Corliss was made a member of the Centennial Commission by President Grant, and at once took a great interest in preparations for Machinery Hall. His solution of the power problems was an offer to build one engine to drive all the machinery. Although this was not accepted until less than a year before the opening date of the exposition, the engine was designed, built, and installed one month ahead of time. This famous machine was a beautifully constructed piece of equipment. Two high-pressure walking-beam engines, each 40-in. bore by 10-ft stroke, drove a common crankshaft carrying the 30-ft flywheel, which meshed with a 10-ft pinion beneath the floor. Running at 34 rpm, the rating was 1400 hp. The pinion shaft was 352 ft long. Six-foot bevel gears, spaced at intervals, drove cross-shafts, power being thus transmitted to the whole building. All these large gears were astonishingly quiet, some engineers insisting that mortised wooden teeth were used until their pen-knives showed them otherwise. The engine itself, standing more than 40 ft above the floor, was the marvel of the Centennial. Batholdi, in his report to the French Government, wrote: "The lines are so grand and beautiful, the play of the movements was so skilfully and simply arranged, and the whole machine was so harmoniously constructed, that it had the beauty, and almost the grace of the human form."

Machinery Hall was officially opened by President Grant and Emperor Don Pedro II, of Brazil, who operated the silver handles of two $^3/_4$-in. valves in bypass pipes leading to the cylinders. This furnished enough steam to start the engine, which had already been thor-

[7] See "Alexander Lyman Holley—A Memorial Address," by R. W. Raymond, Trans. A.S.M.E., vol. 4 (1883), pp. 35–74.

oughly warmed up and turned over before their arrival. After they had moved on, the main valves were opened.

The specifications had called for 1400 hp, or two-thirds of that needed for a cotton mill of the same floor area. Mr. Herreshoff, who first started the engine and set the valves, is authority for the statement that the load never exceeded 400 horsepower. The engine was later sold to the Pullman Works, where it developed its full power and was continually on exhibit until replaced by a steam turbine in 1910.



THE PAWTUCKET PUMPING ENGINE, INSTALLED IN 1878

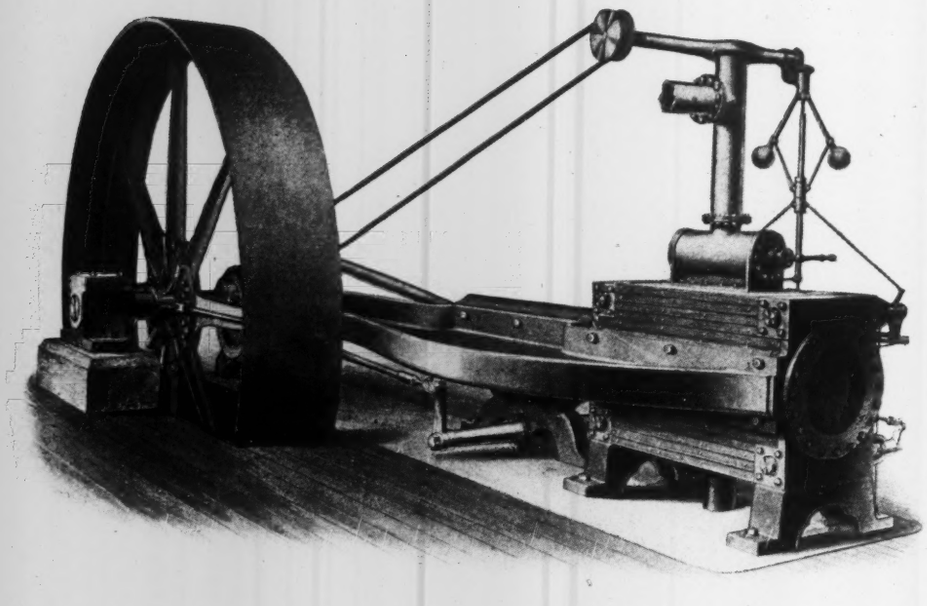
The production of quiet-running flywheel gears in those days must have been a problem. Corliss used full-size wooden models to generate the shape of end-mill-type form cutters. The addendums were on the cycloidal system with the pitch circle of the mating gear for a describing circle. The dedendums were simply clearing curves. This design gave more than four teeth in contact with a 3-to-1 ratio of gears. The cutting was done on a large pit lathe, and to get the proper spacing of the teeth, the pitch circle was actually scribed on the gear and dividers used to locate the tooth centers. This involved great care and as much as a month was required for one flywheel.

Corliss first entered the pumping-machinery field in 1872, when he constructed, for the Providence high-service district, a 5,000,000-gallon-per-day pumping engine to discharge directly into the mains without reservoir or standpipe. Its speed was governed by the water pressure, so that operation was fully automatic. This machine had five steam and five pump cylinders set radially about a central vertical crankshaft, all connecting rods being fastened to a common crank, an arrangement patented by Corliss in 1857. Its maximum speed was 25 rpm, and sometimes during the night it went as low as one revolution in five minutes! The low speed and the large surface area in proportion to the power resulted in excessive cylinder condensation and the low duty of 25,000,000 ft-lb per 100 lb of coal.

Far from satisfied with such performance, Corliss built an experimental pumping station at his plant, using Mr. Herreshoff as test engineer. The next design showed one steam cylinder and ten radial pumps, a reduction gear permitting high piston speed for the engine and low plunger velocity. Little better results were obtained, owing to the excessive friction. A compound steam-jacketed engine was then designed, this being the first time Corliss had used either of these features. This was much more efficient and was later sold to the Lehigh Valley Water Company, of Easton, Pennsylvania. His triumph in the pumping line came in 1878 when he installed the famous Pawtucket engine. This was also a compound with steam-jacketed cylinders, and had vertical walking beams. Its duty of 133,522,060 ft-lb per 100 lb of coal on a test run and more than 124,000,000 on one year's operation were probably world's records for the time. Corliss was held in such esteem in Pawtucket that the pumping station was shut down and draped with mourning on the day of his funeral.

In the middle eighties, Corliss became interested in mass production of steam engines with interchangeable parts. He virtually shut down on sales for a long period while the shop was being rearranged for line manufacture and while a large number of special machine tools were designed and built. Following life-long practice, all of this work was done in the Corliss shop under his personal supervision. Before the value of the change could be tested, Corliss died, on February 21, 1888.

During his life he received many honors. In 1857, the Maryland Institute for the Promotion of Mechanic Arts gave him a gold medal. 1867 brought the Paris International Exposition award. In 1868 came the Montyon Prize, from the Institute of France, and in 1870 he received the Rumford Medal for "an invention which unequivocally tends to promote . . . the good of mankind." Brown University gave him an honorary degree of Master of Arts the same year. In 1873, a diploma of honor of the Vienna International Exposition was



AN EARLY CORLISS ENGINE IN WHICH THE BOX BED HAS BEEN REPLACED BY THE GIRDER OR "WHALEBACK" TYPE OF FRAME

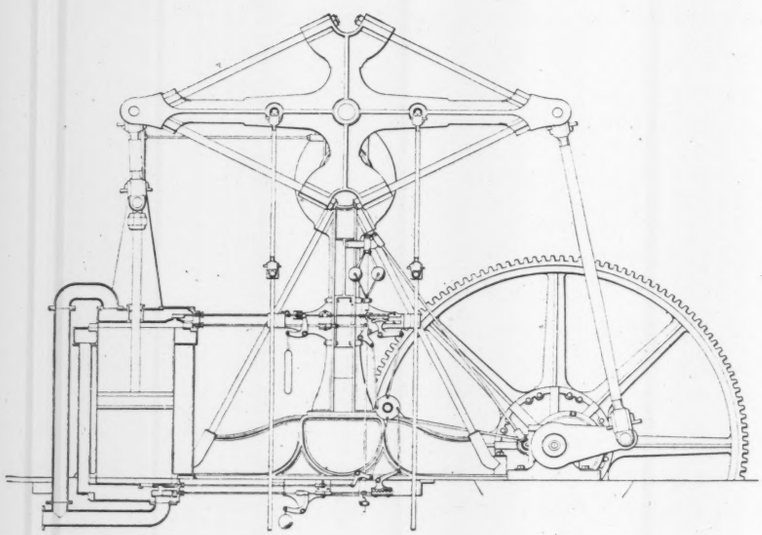
awarded, as previously noted. The Centennial brought further recognition, and in 1886 he was made an officer in the Order of Leopold, by the King of the Belgians.

Corliss' personality was as interesting as his career. Mr. Tallman describes him as "a dignified, well-dressed, tall, and handsome individual, with overhanging eyebrows, piercing dark eyes, clean-shaven face, and two rather protruding upper side teeth, which made me instantly think of Thomas Nast's drawings and caricatures of Uncle Sam. . . . He generally wore a light long-tailed coat and a high pearl-gray stove-pipe hat. He would stand around the shop sometimes all day and would be as immaculate at night as he was in the morning; as far as dirt and oil were concerned, he seemed to lead a charmed life. . . . If his hat was tipped well back, we would allow ourselves to be seen as he came down the track in the center of the shop. If, however, his hat was drawn down over his eyes and his lips parted the least bit, we all did our best to hide behind some machinery, as this latter position of his hat was a sign of bad weather."

Perhaps his most prominent trait was self-sufficiency. He never bought equipment from other manufacturers if there was a possibility of making it himself. Even when building the Corliss mansion in 1882, no architect was consulted. Drawings and building equipment were made in the shop under his personal supervision, including not only the heating apparatus and thermostatic control, but even the window hardware. Depending little on others for ideas, he never read technical publications. In 1880 he refused the first presidency of The American Society of Mechanical Engineers, giving as an excuse that he disliked working on mechanical problems after hours.

He insisted on being the one and only head of the company, hesitating to delegate real authority to subordinates. New technical ideas adopted came largely from his own sketches. At the same time he was impatient of financial detail, slighting the business office and spending most of the day in the shop or the drafting room. As a result, the company once neglected to send out repair-work bills for a seven-year period. Finally, handing the job to Mr. Du Villard, the company billed and collected about $600,000, all customers paying in full except one who had failed. His failure to build up an organization or to develop an understudy resulted in the rapid decline of the Corliss Steam Engine Company after the death of its leader.

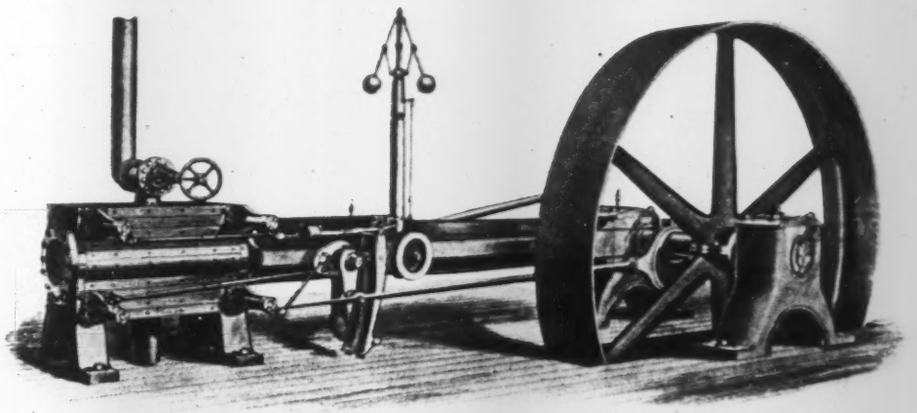
He had pronounced theories in design. Customers' orders not agreeing with these were generally refused. Thus on one occasion he declined to build a double-eccentric engine on the ground that his valve gear was such that one was ample.



FIRST CORLISS ENGINE WITH DROP CUT-OFF CONTROLLED BY THE GOVERNOR

His religious views were firm. Tests on the Pawtucket engine were continuous "excepting for intervening Sundays." He led the successful fight to close the Centennial on Sundays, and later, when the grounds were thrown open on that day, his engine was covered.

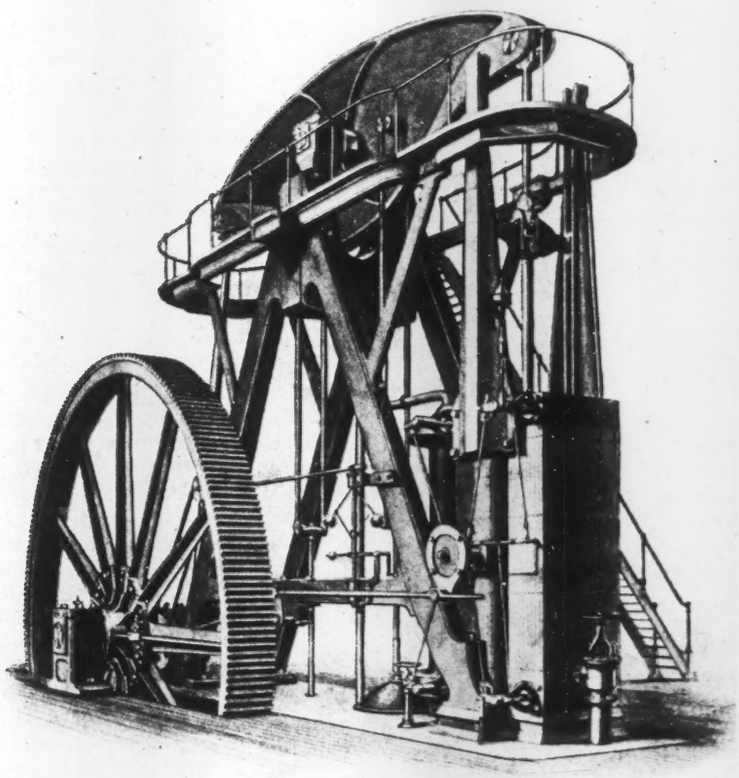
He was generous and kind-hearted, making many gifts to educational and charitable institutions. Work, was never expected to interfere with an employee's attendance at weddings, funerals, or similar family obligations. Informed that a robin's nest had been built in the wheels of the only truck for shipping large boilers, he made a customer wait until the nest was vacated.



A CORLISS ENGINE WITH SPRING VALVE GEAR, BUILT ABOUT 1864–1865

He took considerable interest in public affairs, spending several years in the General Assembly of Rhode Island, and being a presidential elector in 1876. He also served on the commission to build the Providence City Hall. When the railroad terminal situation in Providence required solution, he took an active part in the discussion, making models and even paying the expenses of a public meeting to disseminate his views. In a characteristic way he had formed strong opinions and could see no good in his opponents' suggestions.

A side of his character is shown by the following extract from a letter written in 1870: "I wish that I might support for public office no man who would spend one dollar to succeed even against thousands spent for his defeat. I utterly abhor all transparent fallacy which is expressed in 'fighting fire with fire' or 'among Romans doing as the Romans do' or 'fighting a man with his own weapons.' My maxim on the contrary is fight square and above board always and to the end, and, if the opposition is otherwise minded, adopt none of their devices."

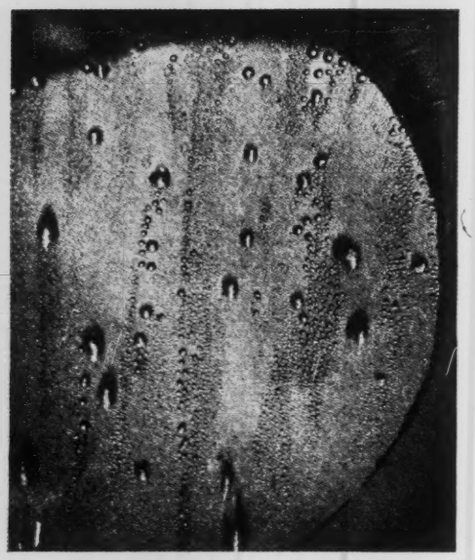


A CORLISS ENGINE WITH GEARED FLYWHEEL, ABOUT 1870

Such was the life and work of George H. Corliss. What was his significance to American engineering? Undoubtedly he should be considered in the forefront of the early and middle eighteenth-century mechanics and inventors whose ingenuity did so much to make American industry preeminent from a mechanical standpoint. In the steam-engine field he was the first to develop a simple, practical scheme to give a variable cut-off by governor control, the advantages of which had been vaguely known for twenty years. His energy and faith in the value of his invention were responsible for the rapid popularization of the idea in this country, while it was widely copied in Europe after his exhibit at Paris. Throughout the world, engines of this type were given his name. With the great saving in steam consumption and the improvement in regulation over previous practice, Corliss should be considered one of the leading pioneers in the development of power generation from Watt to the present day.

DRIP CONDENSATION[1]

By F. A. MAX WULFINGHOFF[2]



POSITIVE DRIP CONDENSATION

HYBRID FILM AND DRIP CONDENSATION

THERE is apparently a great divergence between practical applications and laboratory results on heat transmission in heat-exchanging and condensing apparatus. Even in actual practice there is a wide variation in the rate of heat transfer assumed or allowed by the designer. In actual condenser installations, the design heat-transfer rate varies from 350 to 900 and even 1000 Btu per sq ft per hr per deg F mean temperature difference. In a paper presented to the Heat Research Committee of the V.D.I., Dr. Roecke, of Bitterfeld, reported surface conductance values of more than 8000 Btu per sq ft per hr per deg F mean temperature difference.

The reason that one cannot apply such high values to actual installations is thus explained: The very high heat-transfer rates developed by Roecke are due to drip condensation, a phenomenon which is less likely to occur in large condensers than in laboratory apparatus. The production of isolated drops requires feeble steam currents and exceedingly smooth tube surfaces.

Drip condensation promotes surface conductance to an astonishing degree. The heat conductance in any spot can be considered as a heat transmission through a condensate layer of varying thickness. This indicates the requirement that the condensate falling down from the upper tubes of a condenser should be deflected by baffles in order to avoid increasing the film thickness on the lower tubes. If we take into account two adjoining spots of the cooling surface, with film thicknesses of a and b, respectively, the heat transfer in these spots will be in proportion to $1/a + 1/b$. The sum $a + b$ is a constant for any given apparatus and operating condition. It will be seen that the sum of the inverse values is a minimum when a equals b; any difference whatever between a and b will yield a greater value. Now this means that the less uniform the distribution of the condensate that is obtained, the greater will be the rate of heat transfer that will result.

This idea was first conceived by Ginabat in 1924. He devised a tube arrangement in which the condensate film dripping from one tube would hit the tube below tangentially. The effectiveness of this design is doubtful because the film might be atomized into small particles as soon as it leaves the tube above.

The condensate will be most thoroughly scattered if no coherent film is formed at all, but condensation takes place in the form of isolated drips, leaving small spots quite, or nearly, free from water. This case had been observed by Roecke. The size of the drips was 0.15 to 0.20 in. before they began to run down and leave the cooling surface.

Unfortunately, it is difficult to provide for the drip form of condensation in a condenser of modern design where the aim is to keep down weights and volumes, and to obtain high rates of condensation per square foot of surface and per pound of circulating water. Drip condensation, however, is promoted by smooth cooling surfaces. E. Schmidt, of Dantzig, in 1930 observed positive drip condensation on a polished copper surface. When the surface became roughened by oxide formation, film condensation took place in the same spot. The period of drip condensation was extended by polishing and chrome plating the surface. In Schmidt's tests, with a water velocity of about 16.4 fps, the heat transfer rate with drip condensation was 2100 Btu per sq ft per hr per deg F mean temperature difference, whereas with film condensation the transfer rate was only about 900. Heidrichs, of Aachen, who also presented a paper at a meeting of the V.D.I. Heat Research Committee, has shown that surface conductance coefficients of more than 2000 Btu per sq ft per hr per deg F mean temperature difference can also be obtained on the water side, when water is evaporated.

[1] Abridged for publication by W. F. Ryan, Stone & Webster Engineering Corporation, Boston, Mass. Mem. A.S.M.E.

[2] Asbeck, Kreis Ahaus, Westfahlen, Germany.

The Fundamentals of INDUSTRIAL EQUIPMENT POLICIES

By F. E. RAYMOND[1]

In analyzing the fundamentals of industrial equipment policies, Professor Raymond has formulated six obligations of management, as follows:

1 To safeguard the capital resources of the enterprise from undue extravagance or loss, keeping them intact and unimpaired, and at the same time earning an adequate return on them.

2 To maintain the equipment in a ready-to-run condition.

3 To safeguard the capital resources of the enterprise from the hazard of impending obsolescence.

4 To write off all capital outlays at the time that each makes its contribution to the operation of the business, and to recover from sales revenue an equivalent sum sufficient to amortize those same applications of capital, so that the management will be assured of earning back the original investment at the earliest possible moment.

5 To insure perpetuation of the enterprise through the provision of funds for replacement.

6 To maintain inviolate the normal earning power of every dollar invested in the enterprise.

IN VIEW of the turn of events in the business world during the past three years, industrial executives have been forced to weigh the consequences of the rapid mechanization of industry. From the man in the street to the presidents of our largest corporations, not to mention our politicians in Washington, every one is asking, To what extent is mechanization the cause of our present economic and social catastrophe? In fact, it may well be asked if all this technological development is worth while, which on the one hand has raised for a time the general standard of living of the nation and on the other has apparently brought so much misery to many now out of employment. Does industry need all the equipment that has been installed in the last few years, much of which is now idle? Does it need more complex, more highly refined and automatic equipment in the future, or does it need more general-purpose equipment that is adaptable to rapidly changing business conditions and less likely to displace human labor?

The final answer to these perplexing questions will not be forthcoming until economists, engineers, and sociologists have a greater knowledge of the situation or can agree upon the causes[2] which brought it about. In the meantime, the business executive must decide the best course he can pursue to bring back profits and to place his own enterprise once more on a firm footing, recognizing that conditions can never again be quite what they were.

What policy, then, must the executive adopt toward his industrial equipment? Must it be scrapped while it is still capable of productive operation? Must new equipment be purchased to rehabilitate plants so as to take advantage of technological developments made in this period of enforced inaction? If so, what types of new equipment should be purchased and where will the funds be found to finance these purchases?[3] To decide on these questions, the executive must have a thorough comprehension of the fundamentals which underlie all equipment policies and recognize the obligations which must be fulfilled if all interests in the business are to be satisfied.

For the most part, the problem of industrial equipment is nothing new or peculiar to the present situation. If anything, the situation in which industry finds itself, apart from the effects of the business cycle and natural economic change, is probably due to an ignorance or a disregard of the fundamentals on which equipment policies should be based. Much confusion has arisen in discussions of equipment and equipment policies because owners and administrators of businesses, bankers, operating executives, and accountants, all of whom, in one way or another, are particularly concerned, are affected by such a wide variety of interests. It is the purpose of this paper to point out, from the experience gained by recent research,[4] factors which should be a guide to executives in the conduct of their enterprises.

BASIC CONSIDERATIONS FOR EQUIPMENT POLICIES

Essentially, the problem is a financial one, dealing as

[1] Associate-Professor of Industrial Research, Massachusetts Institute of Technology. Cambridge, Mass. Assoc-Mem. A.S.M.E.

[2] See "The Economics of Machine Production," by R. E. Flanders, MECHANICAL ENGINEERING, vol. 54, no. 9, September, 1932, p. 605.

[3] See "The Present Problem of the Machine," by J. G. Harbord, MECHANICAL ENGINEERING, vol. 55, no. 1, January, 1933, p. 13.

[4] "Economic Life of Equipment," by H. O. Vorlander and F. E. Raymond, Trans. A.S.M.E., vol. 54 (1932), paper RP-54-2.

it does with the economical investment of capital in productive facilities such as machine tools and other kinds of process equipment, although the solution depends chiefly upon the correct application of engineering, management, and economic principles. The funds invested in the enterprise, whether supplied by the owners or borrowed through long-time financing, should be employed so as to earn, in all events, an adequate return, and at the same time they must be protected as far as possible from dissipation or loss arising from the risks of doing business.

An enterprise may either be overequipped or underequipped. In the first instance its fixed assets represented by equipment may be so great as to place an undue burden of fixed charges upon production, so that with any marked recession of business, costs cannot be reduced sufficiently to prevent an immediate loss. In the second instance the cost of highly skilled labor may be such a large proportion of the total cost or the equipment may be so nearly obsolete that prices cannot be cut low enough, except through ruthless wage reduction, to meet those of a more highly mechanized competitor and still provide a profit.

These cases are, of course, extremes. Obviously, capital requirements differ somewhat characteristically in one industry and another. Moreover, there is but one really correct financial structure and policy for an enterprise which, in view of its operating-cost characteristics, will yield the greatest earning power for every dollar invested. Therefore, should not industrial executives be as cautious and as wise in the investment of capital in equipment as the financial administrators or trustees are in the purchase of securities and in safeguarding the principle and income of the funds placed in their charge?

What, then, should be the correct relationship of money, men, machines, and methods to provide an economic balance for profitable manufacture in view of ever-changing market conditions? Unfortunately, as more and more capital is invested in productive equipment, a condition of diminishing returns on capital is bound to set in. Evidence of this is already becoming manifest in certain industries where the capital cost of securing further improvements in production through mechanization is tending to rise at a more rapid rate than manufacturing costs are being reduced. Some excellent examples may be found in the textile industry. Dean Kimball[5] has shown that, in general, the ratio of the value of products to capital invested has decreased steadily for a number of years. Is industry, then, confronted with an economic limit to mechanization?

Above all else, industrial equipment must earn a profit to justify its place in the factory. Is there any reason why each machine or process unit should not be dealt with in the same manner that Professor Rautenstrauch[6] employs in determining the economic characteristics of an industrial enterprise? One can construct a profit diagram for equipment just as well as one can for a going business concern. There are the total *costs to procure* (price paid vendor and installation costs), the total *costs to own* (interest, depreciation, taxes, and insurance), and the total *cost to operate* (labor, maintenance, rent, and other overhead items).

There is only just so much spread in the cost-price structure of any product that can be allotted to the coverage of those costs arising from the equipment and still leave a margin of profit which will stand as a suitable return on the invested capital. Some of these costs are fixed and others naturally vary either directly or in complex proportion to the volume of production. Furthermore, there is just so much of the product which can be sold in any year, depending upon price and other market conditions, and if the total revenue which can be obtained from the sale of the product throughout the life of the equipment is insufficient to cover the total of all of these costs, it will be impossible ever to obtain a satisfactory earning power for the capital invested.

Accordingly, it is essential that industrial executives be in a position to recognize and determine the economic characteristics of the equipment of their plants, or of those which they are contemplating purchasing, so that they can definitely know whether each piece of equipment is or will be contributing its share to the profits of the enterprise. The process engineer will certainly know the specifications of each job in the factory and the mechanical and operating specifications of each piece of equipment in order that the correct machine may be employed on each job. Should not the industrial executive know as well the economic characteristics of each machine for its appointed job so that he can determine, when its useful life is at an end, that it has been able not only to pay for itself in the anticipated time, but also to earn an adequate return on the investment it represents? To know what the economic characteristics should be, the executive must know what obligations, other than those arising from the specifications of the job, are to be met.

THE PRIMARY OBLIGATIONS OF MANAGEMENT

As long as the man of business is solely profit-minded, the obligations which must be considered will be chiefly those of a financial nature, arising from ownership or from the use of borrowed capital. Nevertheless, there are other obligations which in the long run can never be totally disregarded. First, there is the obligation to the customers to maintain or improve the quality of the product and to hand over to them in the form of price reductions a portion of the savings achieved through mechanization, thus meeting competition and spreading the benefits of improved manufacturing methods more broadly. Second, there is the obligation to share with the workers some of the savings of technological improvement in the form of higher wages and make up to them some of the loss resulting from a lessened employment in the industry. Third, there is the obligation to the community to share in the

[5] "The Social Effects of Mass Production," by D. S. Kimball, MECHANICAL ENGINEERING, vol. 55, no. 2, February, 1933, p. 83.

[6] "The Economic Characteristics of the Manufacturing Industries," by Walter Rautenstrauch, MECHANICAL ENGINEERING, vol. 54, no. 11, November, 1932, p. 759.

general burden placed upon society by economic change, as evidenced by increased taxation.

It may be that some portion of the present economic maladjustment is due to a lack of proper consideration of some of these latter obligations. Possibly the profit motive, to survive, must, in the future, rest largely upon the service motive, if capital is to continue to deserve a return upon the funds it has invested in industry. There is little doubt that in the end the machine will continue to be the ally of man in raising the standard of living. Nevertheless, it must be remembered that mankind can only assimilate new conditions at a comparatively slow rate, and so the problem of the industrial user of equipment is to maintain a social as well as an economic balance between man and the machine. What criteria, then, should the industrial executive employ to govern his equipment policies and to maintain an economic and social equilibrium, not only for the immediate present, but for the future good of the community?

Human nature being as it is and as long as no radical change is made in our economic system or our social order, business will continue to be governed largely by the profit motive. Management, then, as trustee, will be primarily responsible to the owners of capital for the funds invested in the business. Therefore, executives must be guided in their actions by the first of all obligations, the financial one: To safeguard the capital resources of the enterprise from undue extravagance or loss, keeping them intact and unimpaired, and at the same time earning an adequate return on them as a suitable reward for the risks of the venture.

CRITERION FOR THE SELECTION OF EQUIPMENT

In order to fulfil the first part of this obligation, management must have some sound basis for purchasing the equipment to be employed. Great care must be taken in the original selection of equipment, because, if the total costs to procure are high in proportion to productivity in terms of quantity, quality, and the total costs to operate, an undue burden must be carried by the product from the resulting high total cost of ownership. At the same time, the specifications of each type of equipment available on the market for a certain class of work in terms of its productivity must be compared with the specifications of the job, and that spread in the cost-price structure allotted to the particular operation in question, to assure a maximum of profit at a minimum of cost. Accordingly, to demonstrate that one particular type of equipment will surpass all others in its economic characteristics and that it should be the one purchased, management must apply the criterion that the equipment must have a maximum of economic productivity. This means that every characteristic must be utilized to the utmost, as otherwise the relation of service rendered to the total cost of that service could never be made a maximum.

The selection of equipment is but the first part of the problem of the safeguarding of capital resources. Even though these funds have been wisely invested, they will be rapidly dissipated if the equipment is not properly maintained and operated. Some provision must be made to obtain, from the sale of the products processed over the equipment, a return of the original investment, together with the total costs to own and to operate. It is not sufficient, of course, merely to charge against the product the costs of materials, labor, and any other expenses which relate directly to the product or are incurred through the control of manufacture, because there are certain charges which arise from the equipment itself. These latter charges go to make up the economic characteristics of the equipment. The more obvious ones are those which arise directly from the use of the equipment, such as power, supplies, and rent for the space occupied, and those which arise from ownership, such as interest, insurance, and taxes. However, in no way do these charges provide for the safeguarding of the original capital from the hazards of doing business. It is necessary, in addition, to recover through sales revenue the original cost of the equipment. Hence, depreciation must be included.

THE CRITERION AND CONSEQUENCES OF PHYSICAL DECREPITUDE

What policies should management follow in this regard? As soon as the equipment is placed in operation, a process of *wear and tear* sets in. Gradually but irreparably, a certain amount of the inherent "good" in the new equipment is transformed into product utility. For this the consumer is willing to pay. The process is one of exhaustion and is similar to that of the depletion of mines. Therefore, management should have a definite policy for prorating to the product in some manner the money value of this loss of inherent "good;" otherwise there will come a time when the productivity of the equipment is exhausted, and unless there is some equity in the scrap value after removal charges, there will be no further opportunity to replenish the original capital. If this is not done, expenses will be understated and profits overstated, and some portion of the dividends paid to the owner may actually represent a return of the capital originally invested.

Furthermore, if no care is taken of the equipment, wear and tear will proceed with great rapidity and with disastrous effects. Therefore, management should never fail to adopt a policy of giving its productive facilities *constant daily attention*, adding the cost of this to the cost of the product as a form of insurance against the too rapid exhaustion of inherent productivity.

Akin to exhaustion is *deterioration*, which brings about a loss in the inherent "good" in the equipment, though it differs in that it proceeds whether or not the equipment is operated. It is a natural process of disintegration occasioned by the conditions and environment surrounding the equipment. If allowed to continue without some preventive measures being taken, the "good" is again removed and the equipment becomes useless before it has a chance to pay for itself. Accordingly, management should see that all equipment is maintained in a perfect condition, whether it is operated or not, and that the cost is taken out of the revenue from

the product as insurance against the unnecessary wasting away from natural causes; otherwise, the owner will again be deprived of the opportunity of recovering his original investment.

Furthermore, there is a loss of productivity through accidents. This hazard can hardly ever be foreseen, though in many instances such loss can be minimized by inspection, training, and safety campaigns. The severity of the accident determines the extent of *damage*, which in some instances may render a valuable piece of equipment worthless. More often, the loss in productivity can be replaced through repairs. Therefore, management should pursue a policy of continual rehabilitation of its productive facilities to minimize the chance of loss through neglect or untoward occurrences.

Accordingly, it becomes evident that the forces of wear and tear, deterioration, and damage are continually at work, tending to remove and thus to diminish the inherent productivity of all industrial equipment and to bring on a state of *physical decrepitude*. Even though the management undertakes an aggressive policy of upkeep, maintenance, and repairs, the forces of wear and tear will eventually so reduce the inherent "good" of the equipment that it ceases to be of any productive or service value. Consequently, there is a time criterion limiting the period within which any equipment can be expected to justify itself financially, namely, the *physical life*. If equipment is to fulfil its appointed task and retain throughout the entire span of its useful life its highest state of productive efficiency, a second obligation must be assumed by management: To maintain the equipment in a ready-to-run condition.

THE CRITERION AND CONSEQUENCES OF OBSOLESCENCE

This is not all. Business is dynamic, never static. Change is the order of the day. Men are continually thinking out new and better ways to do things, and while the original equipment is being run, research is going on, inventions are being made, and developments are taking place. Equipment will eventually appear so far ahead of all present types in performance and economy that management cannot afford not to discard present equipment and install that of latest design. The business itself may have changed, demanding equipment of a different nature. Styles and designs will change with the whim of the customer, terminating the demand for what has been heretofore a staple product, and rendering existing equipment useless. Serious competition may arise not only in the markets for the product but in the markets for labor and capital as well, and with similar results.

Thus, inadequacy and competition, through a change in the original conditions, will destroy the inherent productivity of manufacturing facilities for which there exists no means of redress. This means merely that the relative scale of productivity for equipment has been arbitrarily altered by outside circumstances and a higher standard has been impressed upon industry. This destruction of productivity is the manifestation of obsolescence.

There exists at all times an impending hazard of obsolescence from any one of many sources, sometimes remote and sometimes imminent, and seldom is it possible to foresee exactly when it will occur. When it does, it strikes suddenly and absolutely; there is no recourse from its effect, as the process is irreversible. In many instances, obsolescence approaches gradually, as the changes are not so drastic as to destroy immediately all of the residual productivity of the equipment. This is known as partial obsolescence; but though its effects are not so far-reaching as when complete obsolescence occurs instantaneously, whatever loss in productivity may result is just as irretrievable. Furthermore, though it comes in stages, complete obsolescence will inevitably occur. It cuts off or shortens the useful life of equipment and has no regard for, or relation to, its physical life.

This situation, then, introduces another time criterion for equipment policies which is more vital than the first, namely, the *serviceable* life. This may be defined as the period within which the equipment or facility can render a service through the economical performance of some task. Thus management must recognize a third obligation: To make adequate provision to safeguard the capital resources of the enterprise from the hazard of impending obsolescence.

THE PURPOSE AND NATURE OF DEPRECIATION

As a result of this study, it becomes evident that two distinct types of influence are inevitably at work, either to deplete gradually or to destroy instantaneously the inherent productivity of all industrial equipment. Thus, through physical decrepitude or obsolescence the productive facilities of the enterprise become worthless as far as their original purpose is concerned, and the management is compelled to replace the old equipment with other of more efficient design.

If, then, it is certain that at some time the useful life of equipment will end, how will it be possible for the management, during this serviceable life, to replace it in full and thus maintain inviolate the owners' investment? Obviously, funds must be available for the purchase of new equipment when replacement becomes necessary. This can be achieved only if the management recognizes that the initial investment in equipment is at any time represented in part by the undepreciated value of the property and in part by funds recovered from sales revenue during the preceding period of operation.

If no such accumulation has taken place throughout the serviceable life of the present equipment, no funds will be available to replace it. Of course, some funds can be obtained through sale in either the second-hand or scrap market. If the equipment is not worn out and has been displaced chiefly because of economic necessity, it can sometimes be transferred to other work which does not require such extreme productive characteristics, and the department from which it is removed can be credited with a greater amount than can be realized through sale, in accordance with its recognized value in the new location. Furthermore, an opportunity is

thus provided to continue the accumulation of funds for repayment of the original investment.

In no case, however, will resale, scrapping, or transfer realize the initial value of the equipment represented by the original capital outlay. Additional funds, therefore, must be secured in some manner to make up any deficiencies in total value. Fundamentally, new capital cannot be justifiably obtained for merely the replacement of existing equipment from the issuing of long-term securities, unless some of the capital earlier employed in the enterprise has been returned to its original owners, whether stockholders or creditors. Any such practice will only increase the liabilities of the enterprise upon which the cost of capital at least must be paid. Unless there has been a corresponding increase in product sold to offset these additional fixed charges, the earning power of the enterprise will be automatically reduced. Such methods of financing are only legitimate when the business is being expanded. Only in the cases where dividends have consisted in part of a return of capital to its owner does this form of securing new funds become permissible.

The only way to give adequate protection to the proprietary interests and replenish the treasury by an amount equal to the value of the equipment which has gone into the product is by means of *amortization* of the original investment, which will insure that the capital outlay is completely repaid before obsolescence occurs. In so doing, two things should be borne in mind:

First, it must be ascertained within reasonable limits of accuracy whether or not the total anticipated sales revenue for the serviceable life of the equipment will be sufficient to provide the total funds required for amortization over and above the total cost of fulfilling all other obligations.

Second, there should be no obligation to repay from current sales revenue more than the original investment. Provision for improvement must be handled as a separate problem. In fact, the surplus account should be looked upon not wholly as a protection of the proprietary interests against contingencies or as spoils for the hungry investor seeking extra dividends, but in part as a provision for growth and improvement of the business. Thus the desired funds for replacement will be procured chiefly from current sales revenue and partly from bank balances derived from prior profits.

In this manner, the capital resources can be made self-perpetuating, and when anticipated savings are sufficient to justify expenditures for improvements, the earning power of the enterprise can be maintained and sometimes enhanced.

Since the processes of manufacture operate so as to decrease the original productivity and value of the equipment, and since, as time progresses, change is certain to take place in the underlying factors of any business, eventually destroying all productivity, it is imperative that the books of the enterprise be corrected annually for these losses in property value in order not to misrepresent to the owner the true equity. Accordingly, it has become a recognized principle of accounting to write off each year certain values from fixed assets to account for the losses incurred by depletion or destruction in the productivity of all facilities. The reason lies in the fact that the investment in equipment is in the nature of a prepaid expense and therefore should be charged off to operations at a rate which is as nearly representative as can be of this yearly loss. All expenditures of capital should eventually find their way into the cost of the product in as nearly the correct proportion as possible in order that the management may know its costs more precisely.

From this analysis, it must be concluded that management faces a fourth obligation having two manifestations: on the one hand to write off all capital outlays at the time each makes its contribution to the operation of the business, and on the other hand to recover at the same time from sales revenue an equivalent sum sufficient to amortize those same applications of capital so that the management will be assured of earning back the original investment at the earliest possible moment. This is essential, as capital expenditures cannot be replenished as immediately as expenditures of a current nature.

Provision for the depreciation of fixed assets has long been recognized as an essential part of financial policy and accounting practice, and when properly understood and carried out, should insure the desired protection for the owner and the necessary perpetuation of the investment.

THE NEED FOR A REPLACEMENT RESERVE

Plant executives should be assured that the funds set aside from revenue through depreciation are available when needed for the replacement of equipment. In theory there should be a definite *replacement fund*[7] out of which cash can be immediately supplied for the purchase of new equipment. In practice, however, it is difficult to convince the average business man that, for the sake of convenience to the plant executives, idle cash or securities in excess of obvious needs to support general credit are anything but a waste of valuable capital, all such funds, he believes, should be employed in the business where, presumably, a greater return can be earned on the investment. As long as this attitude persists, the procuring of funds for replacement at the moment they are needed must remain as one of the risks of doing business until it can be shown that business is better off when safeguarded by reserves which have their counterpart in specially appropriated cash or securities.

As a matter of fact, neither extreme situation exists at any time. In practice, once the plant has been in operation for some time, the needs for replacement become staggered, and in rare instances only will a majority of the equipment have to be replaced at any one time. Accordingly, if it is assumed that the rate of production remains practically uniform from year to year, and that the rate of depreciation is proportional

[7] The reader should be careful to distinguish between a "replacement fund" and "depreciation reserves," as the latter refers only to the deduction which must be made to account for a recognized reduction in the stated value of an asset so as to indicate its present value on the books of the company.

thereto, the deductions from revenue made annually for this purpose will, in all probability, provide funds sufficient for the replacement of that portion of the equipment to be supplanted within any year. If an additional investment in excess of the original value of the old equipment must be made to make possible the purchase of facilities having important improvements, such funds should be provided from profits. Usually, the program for replacement follows no such uniform schedules, because more equipment will have to be replaced in some years than in others, and the value of the equipment will never be the same. Hence, the actual outlay for replacement will vary, but over a considerable period, the excess at one time will be offset by lesser expenditures at another, so that within the period of turnover for fixed assets, all replacement will be paid for out of funds accumulated from amortization, except where improvements are concerned.

Since the need for replacement is never uniform, those funds which are in excess of requirements one year should be segregated for use in later years when the demands for funds will be heavier. Thus it is realized that a *replacement fund* is essential but does not necessitate the accumulation of large sums in cash or securities. Only in the case where replacement is deferred over a long period and the fund builds up to large proportions will the arguments of the hard-headed business man find application.

As long as the purpose of depreciation and the process of accounting for it are understood, it should be possible to determine from the financial statements of the business the state of the property investment and the amount of funds which are available each year for replacement. The control of these funds and their expenditure, however, is another matter. The difficulty arises when the time comes to convert these funds into cash in order to replace some equipment. The manner in which this will be accomplished lies entirely in the hands of the financial executive. The important fact remains that funds have been recovered from revenue during the life of equipment which represent the original investment in that equipment. Regardless of the use made of such funds when received, it must be recognized that if the equipment is to be replaced, equivalent funds must be made available to the operating executive when the need arises. The manner of securing such funds is of course optional with the financial executive. Since the latter are generally opposed to setting up special funds in cash or securities, the operating executive must place before his financial colleagues a schedule of replacements and cash requirements sufficiently far in advance of his needs so that the actual funds will be available at the time of purchase. The financial executive must then cooperate with the plant officials and support their requests.

The greatest trouble comes in times of business uncertainty when cash is not easily obtainable. The opportunity still exists for some one to demonstrate beyond any doubt that in the long run it is economical to maintain a fund for replacement. There is an excellent possibility that with the certainty of available funds, opportunities for purchasing equipment of improved design can be seized upon that will result in savings in manufacture sufficient to offset any loss in earnings. If this could ever be proved beyond all doubt, the operating management would be assured of its desired replacement fund. In any event, the conclusion is inescapable that there is a fifth obligation which management must recognize if the total capital resources are to remain unimpaired: To insure the perpetuation of the enterprise through the provision of funds for replacement.

PROTECTION AGAINST ECONOMIC HAZARDS

If management recognizes these five obligations, there is little likelihood that the resources of the enterprise will be impaired by the vicissitudes of business. However, there is still one hazard brought about by general economic conditions which may tend to diminish the value of the capital resources, or of the equipment in which they are invested, without depleting or destroying their inherent productivity. It is well understood that the value of money will vary over a period of time in relation to the value of commodities. This change in the purchasing power of the gold dollar will alter the values of property and prices of goods which it commands, as well as the wages of both capital and labor and the return which the investor receives as a reward for the risks of doing business. If such losses are likely to occur, it would seem that, as long as protection to business from other hazards can be supplied, some provision also should be made to neutralize the adverse effects of this one. The fact is that this hazard is so broad in its influence that it can hardly be classed as a risk pertaining to any individual business enterprise. An apparently effective way to cope with it, as conditions appear at the moment, is through national economic planning[8] carried on at best on an international scale, which will require the concerted and cooperative action of all the business men in the world.

In respect to any individual concern, the only way to protect proprietary interests is to retain in the business earnings, which will appear as surplus, equal to any conceivable shrinkage in values resulting from changes in basic economic conditions. Excess earnings at one time should not be dissipated entirely in dividends until the management is absolutely certain that the remaining surplus is sufficient to cover all contingencies.

Similarly, the process of deflation at the time of business depression will affect the value of equipment. Industry is most actively engaged in the purchase of equipment during the stages of the business cycle when greater productive capacity is required or when more efficient manufacturing methods are demanded. At such times, prices of all commodities, including those of capital goods, are rising, and values are becoming more and more inflated as credit is expanded. With the down-

[8] See "The Problem of Economic Balance," by S. H. Slichter, MECHANICAL ENGINEERING, vol. 55, no. 2, February, 1933, p. 95. Also "The Trade Associations' Part in Coordinate Planning," by E. S. Heermance, Ibid., p. 101.

ward turn of business which will eventually follow, the business executive must recognize that much of his most up-to-date equipment is overvalued in view of the lower price levels, and that he may have to write off as a loss that portion of the investment represented by the inflation originally incorporated in the purchase price of such equipment. Industry today is confronted with just such a situation. In some cases this resulting shrinkage in values must be accounted for so that the books of the company will show the present worth of all such assets of the business, since the reduction in value will be greater than that already provided for through the normal process of depreciation. Consequently, surplus again must be drawn upon, as it is the only safeguard the business has from all forms of economic hazards.

THE CAUSES OF THE NEED FOR REPLACEMENT

Now that there is some reasonable expectation that funds for the replacement of equipment can be secured as need arises, the next questions in the formulation of equipment policies are: When should replacement take place and what type of equipment should be selected? The causes of the need for replacement are three: decrepitude, inadequacy, and obsolescence. As these three causes govern the life of equipment, *time* is the factor which stands as the unit of measure of the usefulness of all industrial facilities.

If physical decrepitude is the only factor terminating the useful life of equipment, its period of service will in all probability be long and can be measured by its physical life. If obsolescence, either from trade factors or technological improvements, is to terminate its useful life, its period of service will end suddenly, and can be measured in terms of its serviceable life only, through a knowledge of or an ability to forecast design or style change, progress in research, and consumer habits and preferences. If inadequacy from the economic pressure of business circumstances is to terminate the useful life of equipment, its period of service will be measured again in terms of its serviceable life, but this time by the disappearance of the margin which has represented earning power. Accordingly, some more highly developed counterpart must be purchased which will show greater operating efficiency and produce sufficient economies to restore, at least to normal, the earning power of the capital invested in it. In either of these instances, the useful life of the existing equipment must be considered closed and new equipment must be purchased.

THE TEST FOR THE TIME FOR REPLACEMENT

It behooves management to be continually testing all its productive equipment for inadequacy against the criterion of serviceable life, and scanning the technical horizon for new developments in design and improvements in the economic characteristics of equipment. Less concern need be had over the effects of physical decrepitude, as the physical life of equipment can be determined on a fairly reliable basis, and in all probability some other cause will operate to terminate its useful life before this one assumes serious proportions. If physical decrepitude is the only cause for replacement, equipment identical to that which has become worn out can be installed with entire satisfaction. On the other hand, if obsolescence from trade factors brings about the replacement of equipment, capital will be forced to seek more profitable investment, and this will require the purchase of entirely different types of equipment. This is tantamount to starting a new business, and a new cycle of selection and replacement of equipment will be set in motion.

It becomes evident, then, that the first criterion of replacement is *economic necessity*. Apparently, it arises solely from inadequacy; that is, from the need either to improve the processes of manufacture or to introduce economies in operation, whether brought about by internal or external pressure. The result is a better product produced at the same or lower cost, or the same product produced for its former cost and at the same time absorbing either increases in wages, capital charges, or taxation, or decreases in price, and possibly providing for an enhancement in earning power.

THE ULTIMATE CRITERIA OF REPLACEMENT

From this point on, the problem narrows down to one of selection, and becomes one of comparison between the economic characteristics of the equipment now in operation and those of equipment of most recent design which is fully adapted to the task in hand. If in such a comparison it can be demonstrated that any one of the new types can, in a reasonable time, effect economies sufficient to pay for itself and attain the same earning power which the present equipment originally had, thus discharging all obligations incurred by the change, replacement should be made immediately. If it is demonstrated that more than one of the new types available can fulfil this requirement, the one which can do it in the shortest time is the one to install. In all events, it must be assured that the proposed type, whichever it be, must satisfy these requirements before its own serviceable life is terminated by inadequacy or obsolescence. Accordingly, the second criterion of the time to replace equipment is *economic superiority*.

In the eventuality, however, that no equipment can be found with the requisite amount of economic superiority to meet all requirements and yet the selection of some type can be justified in all respects except that of being able to realize the full earning power required, it undoubtedly will prove wiser in the long run, especially when competition is severe, to purchase the best equipment available and take advantage of its operating characteristics, because in all probability the loss in earning power and in competitive advantage will be less than it would be should the present equipment be retained. Whenever such a loss has been incurred, it must be borne in mind that consideration should be given to it as a factor in determining when the new equipment itself will have to be replaced and what type should be installed to effect the necessary economies.

Otherwise, if it is of any appreciable magnitude and dividend policies remain unchanged, it will constitute a drain on surplus which cannot be offset legitimately from any other source in the business.

If, however, no equipment can be justified on the basis of its economic superiority, it will be wiser to await further development in design and retain the present equipment. Of course, it sometimes happens that the economic conditions in the trade or even in the country as a whole may be so adverse that normal returns on investment cannot be expected. In such a case, the requirements for earning power must be revised and such equipment selected as will result in the least reduction possible.

THE NEED TO SAFEGUARD EARNING POWER

So far in the discussion, attention has been directed solely toward the obligation to safeguard the original investment. From the foregoing remarks, it also appears that technological development and competition will inevitably bring about a situation which tends to reduce the effectiveness of invested capital and lower its earning power. Therefore, management, in the consummation of its equipment policies, must select for replacement those types of equipment which will have sufficient economic superiority over existing types not merely to safeguard the original investment but particularly to maintain at least the same earning power for every dollar invested.

The point to remember is that the purchase of new and more highly refined equipment will entail a capital outlay greater than that for the present equipment. Because of this, if no provision is made to increase the margin in the cost-price structure out of the savings realized by a change in equipment, these original dollars, which supposedly represent an adequate return on the investment in the present equipment, will of necessity represent a lesser return on that in the new equipment. Since all savings brought about by the new equipment must in the first place go to the fulfilment of the obligation to replenish the capital resources of the enterprise, savings can only be applied to building up earning power after the equipment has paid for itself. Therefore, if it is essential to retain the original earning power, management must have definite assurance that these savings can at least accumulate between the time this first obligation is discharged and the time the serviceable life is terminated by obsolescence or inadequacy, to a total amount which, when divided by the value of the investment and the time it has taken to acquire it, will equal this anticipated rate of return on the capital expended. Accordingly, there is a sixth obligation of management: To maintain inviolate the normal earning power of every dollar invested in the enterprise.

THE MEASURE OF ECONOMIC SUPERIORITY

Since economic superiority is the criterion for determining the time for replacing existing equipment, some measure for evaluating it must be sought if a satisfactory comparison is ever to be made. Throughout much of the previous discussion it has been stated that equipment must be capable of discharging certain obligations within a given period of time. Accordingly, *time* is the logical unit of measure for economic superiority.

From the relationships brought out in this discussion, it is possible to compute[9] the time in which any type of equipment, when compared with one of an earlier design, can both pay for itself and attain an equal rate of earning power. This period in the life of the equipment can then be compared with the estimated serviceable life based upon a forecast of the impending hazard of obsolescence or the known physical life of all such equipment. If this period is less than either of these time criteria of usefulness, there is every likelihood that all obligations, particularly of a financial nature, will be fully satisfied. If this period is greater than either, there will be a reduction in or complete loss of earning power, and in the latter case, there may even be an impairment of the capital resources of the enterprise. Accordingly, this period, which extends from the time when the equipment is installed and placed in operation to the time when it can surpass the earning power of its predecessor, has been designated as the *economic life*. Thus, a definite and final measure of economic superiority can be evolved.

In many instances, however, it has been found advisable to disregard the test of equality in earning power and substitute an arbitrary time criterion of somewhat shorter duration for the economic life, because it is believed to be just as satisfactory and much easier to compute. The justification for this approximation can be illustrated simply if it is assumed that obsolescence will not terminate the serviceable life for four years and that all equipment is expected to pay for itself in less than two. Should the anticipated return on all investment be ten per cent per annum, the full earning power for any two-and-a-half-year period will be completely realized in six months. Therefore, within the first two and a half years of the life of the equipment, all obligations for safeguarding the investment and attaining a desired earning power will be fulfilled, even though the first two years are required to discharge the first portion of these obligations. This leaves a margin of one and a half years as a protection from the too sudden occurrence of obsolescence. Since it takes so short a time to make up for the loss of earning power during the period of amortizing the investment, in general practice it is deemed unnecessary to consider the equality with respect to earning power. Accordingly, in such instances the *time for the equipment to pay for itself* alone is preferred as the measure of economic superiority, as the reliability of this approximation becomes questionable only when a relatively high rate of earning power is demanded for all capital invested, and when the exigencies of the business require a rapid replacement of equipment.

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[9] See "Economic Life of Equipment," by H. O. Vorlander and F. E. Raymond, Trans. A.S.M.E. (1932), paper RP-54-2, especially the "Functional Rate of Return" and the "Relative Earning Power of Equipment" on pages 44 and 45.

TABLE 1 EQUIPMENT REPLACEMENT ANALYSIS

Present Equipment..... Age..... yr Department.....

Proposed Equipment..... Made by.....

Operation..... Performed on.....

The method of comparison is to tabulate the out-of-pocket expenses which differ for the present and proposed equipment and compute for each successive year the cumulative total for such expense for both types of equipment. Cost items which are identical for both present and proposed equipment may be omitted.

Item	Period	1933	1934	Total, 2 yr	1935	Total, 3 yr	1936	Total, 4 yr
1	Estimated output (lb, yd, tons, pieces, etc., for each year)	....	....	xxx	....	xxx	....	xxx
	PRESENT EQUIPMENT							
2	Salvage value, Jan. 1, 1933, in cash (same value throughout)	....	→	....	→	....	→	....
3	Less salvage value, Dec. 31, each year	....	xxxx	....	xxxx	....	xxxx	....
4	Net reduction in value of equipment	....	xxxx	....	xxxx	....	xxxx	....
5	Interest on item 2 at 6 per cent	....	....	....	....	....	....	....
6	Taxes	....	....	....	....	....	....	....
7	Insurance	....	....	....	....	....	....	....
8	Maintenance and repairs	....	....	....	....	....	....	....
9	Net-material cost	....	....	....	....	....	....	....
10	Direct labor of operator	....	....	....	....	....	....	....
11	Indirect labor	....	....	....	....	....	....	....
12	Supplies	....	....	....	....	....	....	....
13	Power	....	....	....	....	....	....	....
14	Rental charge	....	....	....	....	....	....	....
15	Other costs	....	....	....	....	....	....	....
16	Net out-of-pocket cost (cumulative)	....	xxxx	....	xxxx	....	xxxx	....
	PROPOSED EQUIPMENT							
17	Price to be paid vendor	....	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx
18	Freight and delivery	....	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx
19	Installation cost	....	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx
20	Total cost ready-to-run (same value throughout)	....	→	....	→	....	→	....
21	Less salvage value, Dec. 31, each year	....	xxxx	....	xxxx	....	xxxx	....
22	Net reduction in value of equipment	....	xxxx	....	xxxx	....	xxxx	....
23	Interest on item 20 at 6 per cent	....	....	....	....	....	....	....
24	Taxes	....	....	....	....	....	....	....
25	Insurance	....	....	....	....	....	....	....
26	Maintenance and repairs	....	....	....	....	....	....	....
27	Net material cost	....	....	....	....	....	....	....
28	Direct labor of operator	....	....	....	....	....	....	....
29	Indirect labor	....	....	....	....	....	....	....
30	Supplies	....	....	....	....	....	....	....
31	Power	....	....	....	....	....	....	....
32	Rental charge	....	....	....	....	....	....	....
33	Other costs	....	....	....	....	....	....	....
34	Net out-of-pocket cost (cumulative)	....	xxxx	....	xxxx	....	xxxx	....
	DIFFERENCES IN CUMULATIVE TOTALS END OF EACH YEAR							
35	In favor of present equipment	....	xxxx	....	xxxx	....	xxxx	....
36	In favor of proposed equipment	....	xxxx	....	xxxx	....	xxxx	....

NOTES: Since the present cash cost of keeping the present equipment and the cost of installing the proposed equipment are entered successively in the columns of cumulative totals in their respective sections, and since the estimated salvage value of each type of equipment on December 31 is deducted, the factor of depreciation is provided for.

The difference in the total cash outlay involved in producing the same output is the best possible numerical basis for comparison. Such figures are not a substitute for judgment, but they are among the essential data needed for a sound conclusion.

Idle time will be taken care of automatically in the computations, since those items which vary with production are calculated on the basis of the estimated output (item 1), and those which are independent of output are the costs for a full calendar year.

The actual time value of this shorter period can, in turn, be easily determined by calculating the *break-even point;* namely, the instant at which the original investment in the new equipment and any other financial burdens have been repaid in full and beyond which the new equipment definitely shows its economic superiority over the old. The break-even point is the ratio of the difference between the gross investment in the new and the present salvage value of the old equipment and the difference between the totals of all their annual out-of-pocket charges and costs, respectively.

A more satisfactory way of determining when some proposed type of equipment will pay for itself is illustrated in Table I. In this case, the break-even point is measured by the number of years which are required for the proposed type to show its economic superiority, as indicated by the difference between items (16) and (34). When this difference turns in favor of the pro-

posed equipment and is entered according to instructions under item (36) instead of item (35), the total number of years as specified in the heading of the column in which such entry is made should be used as the approximate value of the true economic life.

TRANSLATION OF FUNDAMENTALS INTO POLICIES

In conclusion, it can be stated that through the recognition of the fundamentals which underlie the employment of equipment in industry and the attendant obligations which management must assume in particular toward the owners and in general toward the workers, customers, and even the community, all of whom have an interest in the successful administration of the business, the industrial executive will have a greater opportunity to formulate the equipment policies for his enterprise and maintain the plant in the most effective and profitable state of operation. Since it is possible to determine quickly the economic life of all equipment which it is proposed to install and to compare this with what is known about its probable serviceable or physical life, management can capitalize every opportunity to modernize its plant without risk to the credit, the financial resources, or the earning powers of the enterprise.

For lack of a thorough knowledge of the situation, it has become rather generally the practice to set up some arbitrary limit within which all equipment must pay for itself. If too severe a limit is established, many advantageous changes must be passed by, whereas under too lax a policy the capital resources and earning power of the enterprise will be impaired by the too sudden occurrence of obsolescence. A policy which lies between these extremes will protect the enterprise more completely from competition and technological development through a gradual process of improvement, as then, each unit of existing equipment will be subject to replacement as soon as a new type appears which can show a requisite degree of economic superiority.

At the same time, no undue financial burden will fall upon the enterprise when the time comes to replace equipment, because, if depreciation has been fully provided for through amortization and the resulting accumulated funds have been properly earmarked for replacement purposes, purchase can be made when the best prices are obtainable. Likewise there will be no danger of accumulating losses of capital, as the existing equipment will have already paid for itself, or it will be known in advance that the new equipment will be able to carry any unamortized burden of the old without unduly prolonging its own economic life.

Furthermore, the economic life of equipment may be employed as a rational basis for depreciation policies. Industry is in the habit of employing arbitrary rates for depreciation, determined by general technical and economic conditions which have no regard for specific situations. However, the rate of writing off asset value and of replacement-fund accumulation should be such as to complete both processes simultaneously when the economic life is supposed to end. Any arbitrary rate which will extend the process of depreciation beyond this time is likely to endanger its fulfilment, as it has no specific relation to the impending hazards of obsolescence and inadequacy pertaining to a particular case. As one financial executive has expressed it, he never appreciated the full significance of depreciation until he recognized that each unit of equipment had an economic life peculiarly its own. By segregating types of equipment according to their natural economic life span, he was able to budget depreciation and to obtain a more rigid and satisfactory control over this financial burden than he had been able to do in any other way. Accordingly, in each case the reciprocal of the economic life, when expressed as a percentage, should be employed as the rate of amortization of equipment, as this is the industrial executive's only guarantee that the necessary funds will have accumulated when the time for replacement has arrived.

Since it is possible through periodic calculations of economic life to test existing equipment against each new type as it appears and to determine when the present type should be replaced and by what new type, there is no danger that some competitor will have any real advantage because of his equipment. Of course, if style or price changes, labor or economic conditions, or even taxation, rather than technological improvement, are tending to reduce earning power, the process of computing the economic life of equipment can be reversed and used to determine the economic characteristics of some new type which must be designed and installed to effect the necessary economies.

In pursuing an aggressive policy of continuous modernization, the executive must bear in mind the second-hand market for his old equipment. The higher the price he can realize on existing equipment, the more quickly can replacement be made. It should be remembered, however, that discarded equipment which still retains much of its inherent productivity may find its way at an advantageous price into the shop of a competitor and cancel the advantage apparently gained by replacement. Executives, furthermore, must not lose sight of the fact that a given purchasing power in the community can support no more than a given productive capacity in the industry, and that any increase in the capacity to produce must lower prices in the end and reduce earning power. It may therefore be wiser not to replace equipment too rapidly but to hold it throughout its actual economic life and then to break it up, rather than allow it to contribute in any way to increasing competition.

On the other hand, the manufacturers of productive equipment can employ these fundamentals to plan their design and marketing programs and to demonstrate in any particular case the economic superiority of their product. If these manufacturers pursue too aggressive a policy of technical development and design change, they will place too great a burden upon the industrial users of their equipment by forcing, through inadequacy, the replacement of existing equipment before it has had its chance to pay for itself.

Of more importance at the present moment is the

opportunity which this knowledge gives them to demonstrate the practicability of immediate modernization and rehabilitation of plants by calling the attention of industrial executives to instances where existing equipment can be advantageously replaced, at the same time being able to convince them that in the time limit specified, their equipment will pay for itself and earn a satisfactory return on the money invested.

One manufacturer has said that if plants in general were to purchase today for replacement such new equipment as would be able to pay for itself in a year, the entire machine-tool industry would be back to normal; if they were to purchase what would pay for itself in two years, the industry would be operating at capacity; and if they were to purchase what would pay for itself in three years, the industry would have to expand.

Finally, equipment manufacturers and plant executives can employ the economic life of equipment as a measure of obsolescence. If the latest type of equipment on the market at any moment is taken as the standard of comparison, each preceding type can be rated in terms of the economic life of this standard. Thus, when an earlier type is replaced by the latest, should the economic life of the latter be three years, it can be said that the former is one-third obsolete if an economic life of one year is accepted as marking complete obsolescence. If this is carried out for all previous designs, the rate of progressive obsolescence can be determined, and if the trend is projected into the future, it will assist in forecasting the risk of obsolescence for new designs to come.

THE LANGLEY FIELD CONFERENCE

THE National Advisory Committee for Aeronautics is a remarkable institution which the aviation industry is very fortunate to have. Its equipment is unequaled, and its financial resources are large. These resources, scientific and budgetary, are skilfully administered by a disinterested committee of scientists and an able director.

The Eighth Aircraft Engineering Research Conference, sponsored by the N.A.C.A., Langley Field, Va., May 4, 1933, was attended as usual by a representative group from the aviation industry and gave indication of much useful accomplishment. Certain definite directions in the research work stand out clearly. Perhaps the most important problem in the committee's program is that of lift-increase devices. Many such devices have, of recent years, originated with inventors, passed through various university laboratories, and have now been tested with greater thoroughness at Langley Field. The lift increases accomplished are truly remarkable, the record being held by the Fowler variable-area wing. In this device the rear under portion of the wing is made to slide back, while simultaneously, a specially designed Handley Page slot, consisting of an auxiliary airfoil at the leading edge, is put into operation. This combination of lift-increase elements resulted in a total lift increase of 285 per cent. It is true that a device of this character introduces mechanical complication, increase in structural weight, and additional expense in construction. On the other hand, such lift-increase devices, correctly applied, should really improve the low-speed characteristics of the airplane. The autogiro has received favorable popular notice by virtue of its ability to descend at a steep angle so that the landing speed is low and the roll on the ground short. If airplane constructors grasp boldly at this difficult means of increasing lift, they should eventually be able to approach the slow-speed characteristics of the autogiro without sacrificing the high speed of the airplane.

Closely allied with the problem of slow landing is the problem of lateral control. The difficulty of lateral control becomes greatest at high lift of the wing and slow speed of the airplane, yet it is precisely under such conditions that lateral control is most required. Recent investigations of the committee indicate that where a flap to increase lift is employed, an external aileron is almost essential, that is to say, one which is mounted some distance above the wing, and does not form part of the wing. Another method is to use a spoiler in which part of the wing is raised perpendicularly to the air stream to destroy lift on one side and therefore to produce a rolling moment. No system of lateral control is as yet perfectly satisfactory at low speed, and the committee is to be congratulated on its persistent efforts in the solution of this problem.

Perhaps the most striking novelty discussed at the Conference was the cyclogiro, a paddle-wheel rotary-airfoil system. Recently it was announced that Dr. Rohrbach had invented such a plane. An American inventor, H. H. Platt, has carried the cyclogiro idea so close to practicability that a very large wind-tunnel model of this device is in process of construction. Theoretical investigation by members of the committee's staff indicate that a cyclogiro should be able to climb vertically with great velocity, hover, land vertically at zero forward speed, and at the same time have a quite respectable maximum top speed. It is possible that a successful direct-lift aircraft is just in the offing.

In the field of the power plant, perhaps the most noteworthy event of the conference was the announcement that a hydrogenated safety fuel developed by the Standard Oil Company of New Jersey, with a flash-point of 125 F, gave the same horsepower and fuel-consumption characteristics as when the engine was operated on gasoline. In this fuel, therefore, there exists a valuable means of fire prevention on board an aircraft.

ALEXANDER KLEMIN.[1]

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UNEMPLOYMENT RESERVES

An Analysis of Their Effects on the Stabilization of Employment

By JAMES W. HOOK[1]

THE GENERAL impression prevails in the lay mind, and in some other minds, too, that public unemployment reserves, if universally enforced on industry, would stabilize employment, and by so doing, go far toward solving our unemployment relief problems in the future. I propose to examine this general opinion and show how erroneous it is, whether considered from an economic or from a social point of view. In doing this, however, I do not want to give the impression that I disbelieve in reserves. Quite the contrary; I do believe in them. I have been advocating to industry since the beginning of the depression that it provide them just as it now provides any other reserves, and that it do so voluntarily as a matter of social justice and sound business. But in this advocacy I have not fallen heir to the illusion that reserves would be a solution either of the problem of distress growing out of unemployment or of unemployment itself. Moreover, I have always been concerned about their effect upon the economic system.

Stabilization of employment connotes in the average mind that perfect balance between production and consumption which would continuously supply employment and wages sufficient to provide the necessities of life to every person in the country who is able and willing to work. This means, of course, that adjustments to changing demands of consumers, improvements in the standard of living, and variations in the price level must be promptly and accurately made in order that the balance may be maintained.

[1] President, The Geometric Tool Co., New Haven, Conn., and Chairman, Connecticut Unemployment Commission. Mem. A.S.M.E.

An address before the Round-Table Conference on Readjustment in Industry, at the Twenty-first Annual Meeting, Washington, D. C., May 2 to 5, 1933, of the Chamber of Commerce of the United States.

No one will say that this condition in the economic structure is not desirable. It is the condition that economists and sociologists and scientists and engineers have been hoping to bring about for decades. It cannot be brought about by any single measure. It will come, if it ever does come, when we learn how to do such things as to maintain the price level, curtail waste of investments in overbuilt and worthless ventures, more widely distribute the national income to maintain purchasing power, regulate competition, and practice more generally than is now done common honesty and cooperativeness in all human relationships.

Stabilization of employment, therefore, is only a part of the general problem. With it must come these other things which together would insure a continuing balance in the economic system. No one knows for sure which of these things is cause and which is effect. All we know is that if one is present the others would be present also. With this as a basis to start from, let us ask ourselves if unemployment reserves would help in themselves to bring about stabilization, and if so, just how much would they help?

Ewing Galloway, N. Y.

PLANS AND IDEAS ARE FRUITLESS DREAMS UNLESS THERE EXIST INTELLIGENT MEN TO PUT THEM INTO EXECUTION. ECONOMIC INSECURITY CAN CHANGE THE GREAT NATIONAL ASSET WHICH SUCH MEN REPRESENT INTO A SERIOUS MENACE TO OUR SOCIAL AND POLITICAL INSTITUTIONS

HUGE SUMS OF MONEY ARE INVOLVED

There are, in round numbers, fifty million gainful workers in the United States. In normal times, such, we shall say, as 1925, these workers created a national income of $81,900,000,000, of which 57 per cent was paid out in wages, pensions, benefits, and salaries, and 43 per cent to property holders in the form of rents, royalties, interest, dividends, and profits in individual enterprises.[2]

It is estimated that in 1932 the national income

[2] Figures used in this paragraph are taken from Willford I. King, "The National Income and Its Purchasing Power," 1930, and from Prof. M. A. Copeland, of Cornell University, in "Recent Economic Changes."

will show a decline of approximately $41,000,000,000[3] from the 1925 figures. This means that if we were to consider the year of 1925 and its $81,900,000,000 of national income as normal, completely successful stabilization of business in 1932 would have cost the tidy sum of $40,000,000,000. Even adjusting for the drop in prices between the two years, the sum could not be reduced below $30,000,000,000.

These are stupendous figures. And when we remember that we are only considering one year's operations and recall that the depression has been with us three full years and more, they become fantastic. Yet when we talk of stabilization we must mean what we say. Either that, or what is more likely, we do not understand what we are saying.

Reserves to pay unemployment benefits will, in themselves, neither stabilize employment nor solve the unemployment problem. As a matter of social justice, however, they are desirable. And very few will deny that they are coming. . . . It is a great pity that employers will not voluntarily accept the practice of providing them just as they now provide reserves for depreciation, losses in accounts, and other items. Were they to do so, the amounts would be so widely distributed and so obscured from public notice that they would exert no more effect upon the economic system than do surpluses from which dividends are now paid. Herein lies one of the strongest arguments in favor of voluntary action in the creation of unemployment reserves as against compulsory action. But will voluntary action come? Experience to date indicates that it will not. If this is true, then we employers may as well adjust ourselves to compulsion. We cannot argue for voluntary action much longer without producing the goods. If we cannot produce the goods, we cannot consistently oppose the enactment of laws designed to force us to do something which we admit should be done, provided it is done voluntarily.

With these figures in mind, let us examine how far unemployment reserves would have gone toward bringing about stabilization at the start of this depression. First, we must calculate how much the reserves would have amounted to. We shall do this on the basis of the reserves required in Wisconsin, the only state so far to enact unemployment reserve legislation. Under that act a reserve of $75 per employee is required for a limited number of employees engaged in industry. Farm laborers, domestic servants, interstate railroad employees, school teachers, public officers, those employed in governmental relief projects, employees engaged in units of industry employing nine or less, and employees receiving annually $1500 or more are excluded. These exclusions would bring the number of eligible persons entitled to receive benefits under the act to thirteen millions, approximately, in the 48 states. Multiplying this number by $75, the required maximum reserve for each employee, we get $975,000,000 as the maximum reserve fund that could have been accumulated and ready for use at the beginning of this depression. This sum would have been augmented up to January, 1933, by as much, probably, as $225,000,000. Interest also would have accumulated on the fund. Altogether, it is probable that a sum of approximately $1,300,000,000 would have been available on paper for use during the depression through 1932.

WHAT WOULD BE THE ECONOMIC EFFECT OF LARGE RESERVES?

To have used all of these funds would have required that during the depression enough eligible employees had been dismissed or paid wage benefits to have exhausted the reserves. Judging by experience in the depression to date, it is not likely that this would have happened, because many eligible employees have been regularly employed throughout, which means that they would not have been paid any benefits at all. Therefore, to be on the safe side, we shall assume that sums were expended somewhat as follows: $100,000,000 in 1930, $300,000,000 in 1931, and $600,000,000 in 1932. What would have been the effect of these expenditures on stabilization? How far would they have gone toward offsetting a reduction in the national income of $11,000,000,000 in 1930, $29,000,000,000 in 1931, and $41,000,000,000 in 1932, over that established in the normal year of 1925?[4]

At first glance, one would say that the effect would have been very small if, indeed, there had been any effect at all. But that would not be a true statement. One billion dollars distributed in small amounts among many people would not add merely a billion dollars to the national income, but probably ten times that amount. It would be used to buy goods over and over again as it passed from one pair of hands to another. It is not the actual money in the country that represents the national income. Rather, it is the rapidity with which that money is used. If a silver dollar passes among one hundred hands in a year's time, it has negotiated one hundred distinct payments. If, during those passages, it paid wages five times and yielded, say, ten per cent profit to the recipient every other time, it actually served to increase the national income by fourteen and a half times its value. In 1925 there was never more than $5,000,000,000 of currency in circulation in the country at any one time. Yet, as stated above, the national income amounted to $81,900,000,000, showing that actual cash in use in the country, by supplying the base for checks and drafts, was used about sixteen times. In 1932 the ratio had dropped to approximately seven times.

[3] See Bulletin of National Industrial Conference Board, February 20, 1933, which estimates national income for 1932 at approximately $40,000,000,000.

[4] See Bulletin of National Industrial Conference Board for February 20, 1933, which estimates national income in 1930 at $70,700,000,000, $52,700,000,000 in 1931, and $40,000,000,000 in 1932.

Some argue that money paid out in unemployment benefits from reserves previously accumulated would turn over more rapidly than money in the ordinary marts of trade; much more rapidly, in fact, than money paid out in dividends. This is a moot question which there is not time to argue here. There is little doubt, however, but that at the beginning the speed of turnover would all be in favor of payments from unemployment reserves. They would go, for the most part, to pay for food, clothing, and rent, and, as compared with dividends, would much more slowly exhaust their economic effect. It is very probable, also, that they would contribute more to national income than would dividends, also that they would, like wages, have the added advantage of being spent for consumer rather than capital goods. The latter is a most important consideration at the beginning of and during a depresison, when increased consumption of current production is so necessary to maintain carrying charges on the capital structure.

CERTAIN OFFSETTING INFLUENCES

But would there not be offsetting influences? There certainly would be. The setting up of unemployment reserves, translated into its simplest terms, is an effort to set aside purchasing power when it is plentiful for use when it is scarce. And for what purpose? Undeniably, to spread the national income more widely and to do it, when employment is falling off, from reservoirs of purchasing power that were stored up in the form of money and credit when the national income was high. The objective, of course, is good and the only question that arises is—can it be done? Can purchasing power be stored up like gold or silver or wheat?

Limited space prohibits a complete examination of this interesting and enticing subject. It must suffice for the present, therefore, to touch merely upon one phase of it.

Suppose that between July 1, 1930, when the full force of the present depression struck, and January 1, 1933, unemployment reserves, as estimated above, had been drawn upon in the amount of $1,000,000,000. At the beginning of the depression the amount on hand, as already stated, would have been $975,000,000. This latter sum, undoubtedly, would have been invested. Thereafter, for two and a half years, continuing contributions and interest accretions would have brought the reserve funds available, on paper at least, to the sum of $1,300,000,000, as mentioned. If, as has been assumed, $100,000,000, or approximately $16,500,000 per month, had been needed for unemployment benefit payments for the remaining six months in 1930, and $300,000,000, or $25,000,000 per month during the twelve months in 1931, and $600,000,000, or $50,000,000 per month, in 1932, would they have been available, and just what would have been the effect upon the financial end of our economic system of paying them out of the reserve?

There is probably little question but that the payments in 1930 could have been made without difficulty. Prices of prime securities during that year did not decline to any great extent. Investors were converting speculative holdings into investment securities at a fairly rapid rate. This condition continued into the summer of 1931. Thereafter, all prime securities were sensitive to bearish influences. Bond prices fell. Reserves of our traditionally invulnerable institutions dwindled and in many cases disappeared.

Can anybody question that those conditions would have been made worse by vast unemployment reserves under pressure, all the time, of enforced liquidation? Can any one doubt what shrewd traders on the bear side would have done in 1931 had they known that certain public reserves of bonds and other high-class securities were to be liquidated at the rate of $25,000,000 every month in 1931 and at double that rate in 1932? Certainly not. Such traders would have made a point of finding out what those securities were. They would have studied their collateral effect upon other securities. They would have applied bear pressure upon them with perfect safety and with the assurance that the pressure could be maintained month after month as long as the depression continued and unemployment increased.

THE DISASTROUS EFFECT OF DEFLATION

The effect would certainly have been to add to depression influences that were current and growing during the entire troublous period. And the result would have been to contract further the reserves available, so that instead of yielding $1,000,000,000 less a natural deflation discount in actual cash for the unemployed, they would have yielded considerably less.

It will be said that both of these losses would have been offset largely by the reduced cost of living brought about by falling commodity prices that accompanied the depression. If we are only thinking of the reserves in their mass, this, to a substantial extent, would be true. But we cannot think of unemployment reserves in the mass only. We must think of them as an aggregate of thousands of small reserves from which benefits to thousands of individuals may some time be made. To suggest that they should be adjusted month after month to changes in cost of living or depreciation in the total reserve would be unreasonable. To explain variation in monthly or weekly payments to beneficiaries on such a basis would be impossible, and particularly so if the beneficiaries, by contributions of their own, had helped to establish the reserve in the first place. Yet, to continue to pay out a dear dollar for every cheap dollar orginally put in would inevitably leave somebody out of pocket in the end.

Of course, it is within the realm of possibility that even this depression would not have reached its present depths if, at the beginning, a means had been available of maintaining wage payments for a reasonable time while the speculative movement was adjusting itself. I believe we would all agree to such a theory, provided the payments were large enough and distributed widely enough and continued long enough to permit the complete adjustment to be made. It is here, I think, that we

would run into insurmountable obstacles. The amount of reserves that would have been needed would have been too great, and the fact that they must have been converted into cash rather suddenly when everybody was trying to sell and nobody was wanting to buy, would have introduced problems that could not have been met. And if they could have been met, the effect would have been opposite to what was intended. It would have been to bolster up the tottering structure of speculation rather than to force it to adjust itself.

In this entire discussion, the reserves have been limited to the sum of $75 per eligible employee, according to the terms of the Wisconsin act. If there are serious problems involved in the investment and conversion of a reserve built up on such a modest sum, imagine how much more serious they would be if the limits of eligibility were widened and the amount per eligible employee increased. And they certainly would be widened and increased. No one would be willing to say that $10 per employee per week for ten weeks in any one year would be enough to offset the effects of curtailed employment or complete unemployment except in the most minor of depressions. We may be sure that if the principle of reserves for unemployment benefits is established, the amount per employee would be materially increased within a very short time.

HOW CAN THE RESERVE FUND BE MAINTAINED LIQUID?

It will not be denied that before we could make a success of such a program we should have to find a way either to maintain reserves in liquid form or means of stabilizing employment so that reserves for unemployment benefits would never involve unwieldy sums. Otherwise, reserves could never be very much of a factor in stabilization.

Prof. Sumner H. Slichter, of Harvard University, has recognized the difficulty of keeping unemployment reserves liquid and has suggested a way to do it. In a nutshell his plan is this. Unemployment reserves would be deposited in the Federal Reserve Banks. As long as business is brisk, these deposits would exceed withdrawals for unemployment benefit payments. During such periods, these excess deposits would not be available to commercial banks for use in expanding credit, since they would go directly into the reserve banks and be kept liquid. When business slumped and withdrawals for benefits exceeded deposits, such excess withdrawals would quickly find their way into commercial banks and thus ease the credit situation. The effect of all this would be to curtail credit of commercial banks when business was brisk and release it when business declined and unemployment increased. Another effect would be to offset inflationary influences when accretions to the reserves exceeded the withdrawals and control deflationary tendencies when withdrawals exceeded accretions. The form in which the reserves would be kept in the reserve banks, the use the latter would make of them to ease credit at crucial times, and the manner and speed with which they would be returned in the form of unemployment benefits are all pertinent knowledge to a complete understanding of the plan.[5]

Courtesy of American Meter Co.

CRAFTSMANSHIP—THE SKILL OF EYE AND HAND—POSSESSED BY MEN AND NOT MACHINES—AFFORDS INDEPENDENCE AND SATISFACTION UNTIL MENACED BY UNEMPLOYMENT, TECHNOLOGICAL ADVANCE, PHYSICAL INCAPACITY, OR OLD AGE, HAZARDS AGAINST WHICH HUMAN WIT MUST PROVIDE

Professor Slichter's suggestion is deserving of careful study, as are all others whose intent is to point the way to keeping great reserve funds in a state that they could be liquidated quickly during periods of deflation without disturbance to the economic system.

There are some who would not admit that the problem of liquidating reserves is as great as it has been painted, and for proof will point out that dividend and interest payments alone amounted to $6,183,000,000 in 1930 and to $6,279,000,000 in 1931, and that those vast amounts had to be converted into cash from reserves resting in banks. The answer to that is that reserves and surpluses from which dividends and interest are paid are spread about in the country's twenty thousand banks. They are not concentrated and publicly accounted for as unemployment reserves would be. They would not, therefore, exert the same weight upon the economic system or the same influence in speculative markets.[6]

EFFECTS OF RESERVE FUNDS ON NUMBER OF PERSONS EMPLOYED

There is another observation that should be made about the stabilizing effect of unemployment reserves

[5] See "The Problem of Economic Balance," by Sumner H. Slichter, MECHANICAL ENGINEERING, February, 1933, pp. 95–100. See also an article by the same author in the *Harvard Business Review*, April, 1933.

[6] The figures in this paragraph were taken from "Unemployment Insurance in Wisconsin," by Roger Sherman Hoar, 1932, p. 88.

that is too often overlooked. I refer to their effect upon the number that would be employed. No one will deny that a policy requiring the payment of unemployment benefits would create a strong incentive among employers to get along with as few employees as possible. Machinery would be used wherever possible. Closer knit organizations would be developed to lessen the need for human labor. At the same time, however, unemployment benefits would discourage short-time employment for and dismissal of such employees as were needed. The ultimate result of these two influences would be better stabilization, perhaps, of fewer employees—but certainly fewer employees.

In this connection, too, it would be well to ask what effect reserves would have upon the desirable practice of spreading work that has been such a large factor in keeping men and women on payrolls during the present depression. Would it not be to lessen the practice? It would seem so. Employers, generally, would not feel the obligation to spread employment if the state had established a policy by which the penalty for dismissing a person were definitely evaluated. This would be particularly true if, as is done in the Wisconsin act, provisions would be made for paying supplemental wages to employees whose hours had been reduced beyond a prescribed amount.

The conclusion is inescapable, therefore, that unemployment reserves would, in the final analysis, actually tend to force men off payrolls and, on the whole, adversely affect stabilization.

From the purely social point of view, payments to employees who may be dropped from payrolls for no cause of their own making are matters of simple justice. The same may be said for payments that are made to persons kept on payrolls on very short hours. These payments should not be made, however, on the theory that they will stabilize business and employment. They should not be advocated as a solution of the problem of distress that accompanies unemployment. They should be considered simply as a palliative, a means, as it were, of removing some of the fear of interrupted employment and of giving the victim a chance to hold up his head for a reasonable time while seeking new employment. It must not be inferred from this that the removal of fear of short hours, low pay, and sudden dismissal would not, in itself, contribute toward stabilization. It would, of course. It would create a better attitude of mind among the workers by assuring them of an income for a definite future period. If they were put to the necessity of seeking other employment, they would not be deprived of income for a reasonable time while doing so.

Not only is this desirable as a social need, but it is something the stable, dependable, and efficient workers in all fields of endeavor are entitled to. Men and women who have placed complete dependence upon earning a livelihood in the hands of their employers should not be thrust aside without consideration when something happens to reduce or eliminate the need for their services.

SUMMARY

Summing up, it would seem to me that reserves to pay unemployment benefits will, in themselves, neither stabilize employment nor solve the unemployment problem. As a matter of social justice, however, they are desirable. And very few will deny that they are coming. Regardless of the problems involved, the public is demanding them and ultimately will get them. It is a great pity that employers will not voluntarily accept the practice of providing them just as they now provide reserves for depreciation, losses in accounts, and other items. Were they to do so, the amounts would be so widely distributed and so obscured from public notice that they would exert no more effect upon the economic system than do surpluses from which dividends are now paid. Herein lies one of the strongest arguments in favor of voluntary action in the creation of unemployment reserves as against compulsory action.

But will voluntary action come? Experience to date indicates that it will not. If this is true, then we employers may as well adjust ourselves to compulsion. We cannot argue for voluntary action much longer without producing the goods. If we cannot produce the goods, we cannot consistently oppose the enactment of laws designed to force us to do something which we admit should be done, provided it is done voluntarily. Unemployment benefit legislation is pending in some twenty states. Only the depths to which business has plunged and the fear of forcing it further into the mire has delayed positive action in some states so far.

One would think, however, that the disastrous experience that individuals and institutions have had with reserves and surpluses in the last year or two would make our lawmakers very cautious about putting too much dependence in them in the future. Experience, however, much less economic argument, falls flat when pitted against human impulses to mitigate distress such as is caused by long periods of unemployment. The public generally looks upon the latter as a state of being in which the victim is not so much out of work as without the means of purchasing the necessities of life. The attack on the problem, therefore, quickly assumes the form of direct payments in goods or money. This was the case in England and Germany where work relief was abandoned long ago for direct payments. It has proved true in our own country in towns and cities where work relief, always preferred, was soon found to disappear in favor of direct relief.

Legislative proposals to date in this country for making these direct payments have confined themselves to setting forth the amount that shall be paid and the manner in which the funds for the reserves shall be supplied. They do not provide a method for keeping the reserve liquid or from shrinking in value. Perhaps and in view of added complications introduced by the prospects of currency inflation and the regulation of employees' hours and wages, it is time for these extremely important points to be taken into account.

The Problem of the SOLID STATE OF MATTER

By F. ZWICKY[1]

This paper discusses a new and general theory of the solid state which, for the first time, provides for an adequate framework in which all the essential physical properties of solids find their natural place. After stating the problem of the solid state, the author shows that none of the existing theories can offer a complete solution of this problem. This failure is due to the fact that the existence and action of an important type of phenomena in solids remained unrecognized. As these phenomena originate in the simultaneous cooperation of an enormous number of elementary particles (atoms, electrons, etc.), the author has called them "cooperative phenomena." It can be shown that these phenomena are responsible for the very existence of a crystalline state of matter. The most important consequence of the theory was that it led to the discovery of a so-called "secondary structure" of crystals. This secondary structure has a very decisive influence upon many important properties of solids. In particular, it is now possible to account satisfactorily for the complex of mechanical and plastic properties of solids. A real understanding of these properties promises to lead to many new findings of great technical importance.

PHYSICAL properties of solids may be grouped in two classes, structure insensitive and structure sensitive.

Structure-insensitive properties are essentially independent of the previous history of the particular sample of a substance which is investigated. Examples of structure-insensitive properties are the density, the specific heat, the elastic constants (compressibility, Young's modulus, etc.), the thermal coefficient of expansion, the lattice structure, that is, the geometrical arrangement of the atoms in the crystals which make up a solid, etc. These properties are practically the same for single crystals and for polycrystalline samples of the same substance. These properties also change very little on annealing, cold hardening, and the introduction of small amounts of various impurities.

Structure-sensitive properties, on the other hand, may be very different for various specimens of the same substance. They may even differ very much in cases where no apparent differences of the samples can be detected on investigation with the microscope or with X-rays. Examples of structure-sensitive properties are: the mechanical and the electrical breakdown strength of crystals, the hysteresis losses which are related to the mechanical vibrations in solids, the cold hardening of metals and solids in general, the ferromagnetic phenomena, etc. From this enumeration it is evident that the structure-sensitive properties are exactly those which are of the utmost importance in regard to technical applications. For instance, most extensive use is made of the curious phenomenon which is known as cold hardening, without whose assistance the working of metals, especially sheet metals, into desired shapes would be impossible.

It was a great advance in our knowledge of the solid state when M. Laue, in 1912, discovered that X-rays provide a means to investigate the arrangement of atoms in a solid. From the fact that all solids diffract X-rays in regular geometrical patterns, it followed that solids are either single crystals or polycrystalline aggregates. Only in a few cases, substances which are apparently solids, such as glasses, were really found to be supercooled liquids, a conclusion which already had been drawn long before Laue from the fact that these "semi-solids" have no melting point, but rather that they change their physical properties continuously with increasing temperature until they are definitely liquid. The mutual separation of the atoms in the solid state proved to be of the same order of magnitude as the diameters of the atoms themselves, namely, a few times 10^{-8} cm.

The X-ray investigations indicated that the atoms in perfect single crystals arrange themselves in ideal crystallographic lattices. A crystal which geometrically can be described by an ideal lattice will be called an ideal crystal. However, it is possible that no really ideal crystals exist in nature in spite of the fact that the X-ray diffraction patterns very strongly suggest the existence of ideal lattices. It is, in fact, the main contention of this paper that real crystals cannot be completely described by ideal crystallographic lattices, but that the introduction of a so-called secondary structure is necessary if one wants to describe satisfactorily all the physical properties of crystals.[2] This secondary structure, as proposed by the author a few years ago, has no appreciable influence on the observed X-ray diffraction patterns,[3] and therefore has escaped the attention of physicists for a long time. The secondary structure, however, exerts a perfectly enormous influence on the structure-sensitive properties of crystals and solids in general. How one arrives at the notion of a secondary struc-

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This paper is a somewhat modified version of a report which was delivered at the combined meeting, New Haven, Conn., June 23 to 25, 1932, of the American Physical Society and the Applied Mechanics Division of The American Society of Mechanical Engineers.

[2] F. Zwicky, in the Proceedings of the National Academy of Science, vol. 15 (1929), pp. 253 and 816, and vol. 17 (1931) p. 524; also in the *Physical Review*, vol. 38 (1931), p. 1772, vol. 40 (1932), p. 63, and vol. 43 (1933), p. 270; and also in *Helvetica Physica Acta*, vol. 3 (1930), p. 269, and vol. 4 (1931), p. 49.

[3] H. M. Evjen, in the *Physical Review*, vol. 34 (1929), p. 1385, vol. 39 (1932), p. 675, and vol. 41 (1932), p. 265.

ture of crystals will be sketched in a later portion of this paper.

As soon as the geometrical arrangements of atoms into regular lattices were known for a great number of crystals, thanks to the investigations of Laue, Bragg, and others, physicists occupied themselves with the problem of deriving the physical properties of these crystals from the already fairly well-known properties of the atoms which build up these crystals. In the beginning, that is, in the period from 1912 to 1922, physicists paid very little attention to the structure-sensitive properties of solids. Indeed, it did not seem improbable that structure sensitivity was an entirely secondary effect, which had its origin in the polycrystalline structure or in the often ill-defined nature of solid matter. However, extended experiments by A. Joffe and others proved that the best single crystals still possess most of the structure-sensitive properties in an even enhanced degree.

At the same time, theoretical physicists showed that the extremely low mechanical and electrical strength of single crystals could not be accounted for by the atomic theory of ideal crystal lattices. For instance, the theoretically derived breaking strength of ideal rock salt (NaCl) crystals is 400 times larger than the actually observed strength. This discrepancy, with the exception of possibly a few crystals, is quite a general one. In Table 1 the shearing strength S, the shearing modulus G, and the angular displacement δ (angle of shear) at the yield point are given for a few metal single crystals. If these crystals were of ideal structure, the change of angle δ at the yield point should be of the order of magnitude $\delta = 1/2$, instead of a few times 10^{-5}, as it actually is. This would imply that the strength S_i of the ideal crystal against shear should be approximately of the order $S_i = G/10$.

TABLE 1

Crystal	δ in 1×10^{-5}	G in kg/mm²	S_r in kg/mm²	S_i in kg/mm²
Mg	4.94	1700	0.084	170
Zn	2.30	4080	0.094	408
Cd	3.35	1730	0.058	173
Bi	22.8	970	0.221	97
α-Brass	58.6	2240	1.44	224
Al + 5% Cu (annealed)	379	2450	9.30	245

Fig. 1 shows the type of relation between stress and strain as it is actually found for real crystals and the same relation as we should expect it to be for ideal crystals. In it σ is the stress, δ the strain, T the temperature, Y_i the yield point of the ideal crystal, and Y_r the yield point of the real crystal; and $\sigma = S_i$, $\sigma = S_r$ are the critical strengths of the ideal and the real crystal against slipping (gliding) at their respective points of first yield. The diagram, of course, cannot be drawn to scale, as in reality S_i has a value approximately a thousand times that of S_r.

Several facts become apparent from Table 1 and Fig. 1.

In the first place, as already mentioned, real crystals yield for values of the applied shearing stress ($\sigma = S_r$) which are much lower than that ($\sigma = S_i$) expected for the ideal crystal. Furthermore, the plastic deformation (or eventually the rupture) sets in abruptly within the region of perfect validity of Hooke's law. The crystal gives no warning when the yield point is approached by exhibiting deviations from Hooke's law. This is contrary to the expectations for an ideal crystal, which should deviate from Hooke's law long before the actual point of yielding is approached. It is a curious and significant fact that, just on the contrary, the very worst-defined conglomerates of microcrystals, such as steel, alloys, etc., show a behavior such as we would expect for ideal crystals. They indeed exhibit reversible and reproducible deviations from Hooke's law before the yield point is reached. These conglomerates, which really have no resemblance at all to an ideal crystal, possess a strength which in order of magnitude is not much less than the strength of ideal crystals is expected to be, whereas, paradoxically, the best real single crystals possess a mechanical strength which is far inferior to the strength of either deformed (cold-worked) single crystals or polycrystalline samples.

The second strange fact is that a real crystal, after the plastic deformation has started, begins to harden. This hardening in certain cases may be so enormous that the mechanical strength of the totally deformed crystal before it finally disrupts assumes values which are of the same order of magnitude as S_i for the ideal crystal.

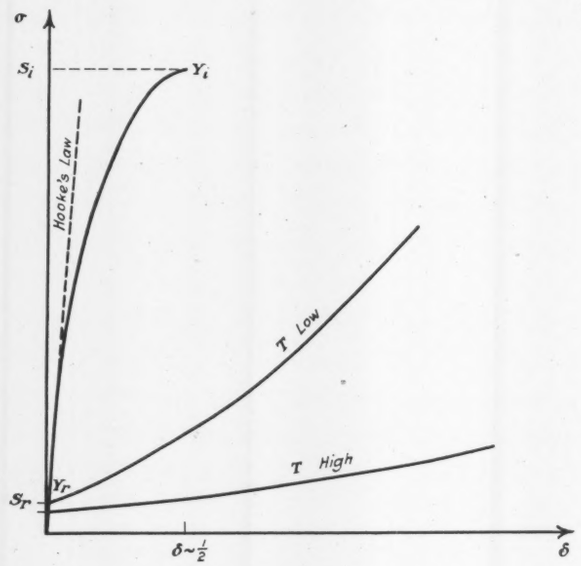


FIG. 1

Stating it paradoxically, we may say of real crystals that the more their geometrical characteristics differ from those of the ideal crystal, the more they behave mechanically as ideal crystals are expected to behave.

Thirdly, the enormous influence of very small amounts of impurities or additions of foreign atoms to a crystal becomes apparent from the last example of Table 1. Pure aluminum single crystals are very weak, having a shearing strength which is certainly smaller than 0.5 kg per sq mm. The addition of only 5 per cent Cu raises the strength to $S_r = 9.3$ kg per sq mm. This strengthening of crystals by foreign atoms is quite a general phenomenon. In the case of NaCl crystals, for instance, their strength against rupture can be increased from about 20 to 100 kg per sq cm if the ridiculously small amount of 0.05 mol per cent of CoCl is added.

Summarizing, it may be said that great doubts must be entertained whether a representation of real crystals by ideal crystallographic lattices is at all justified. These doubts, as has been shown, have their origin principally in the following considerations:

(*a*) The ideal crystal does not account for the existence of the so-called structure-sensitive properties of solids.

(*b*) The theory of the ideal crystals does not account for the surprisingly low mechanical strength of real crystals.

(*c*) An ideal crystal on deformation becomes weaker or

breaks, and the phenomenon of cold hardening of real crystals remains unexplained.

(*d*) The enormous influence of very small amounts of impurities seems incomprehensible on the theory of ideal crystals.

The above considerations suggest that real crystals cannot be completely described by ideal crystallographic lattices. The actual deviations from the ideal crystal, however, cannot be very great, as they are not easily detectable by X-rays or under investigation with a microscope.

THE "IMPERFECTION" THEORY

The following solution for the difficulties just described first suggested itself: It is well known that most of the real crystals show irregular imperfections, such as slip lines, lineage, twinning, cracks, and inclusions of contaminations. It is also known from the work of C. G. Darwin and P. Ewald on the broadness of X-ray lines reflected from real crystals that these imperfections may be of microscopic dimensions and that they exist in even apparently perfect crystals. It was therefore thought that some of these imperfections might account for the existence of structure-sensitive properties of crystals, and in particular that they were the cause of the low mechanical strength. For instance, the low mechanical strength may be due to cracks, and structure-sensitive properties might be caused by varying amounts of foreign substances imbedded in these cracks and also by varying the cracks by various treatments of the crystal. It was A. A. Griffith who suggested this possibility and A. Smekal developed it later. These investigators assumed that, even in the best grown crystals, imperfections of mechanical and of chemical nature occur. Smekal calls them *Lockerstellen*, that is, regions where the atoms are more loosely bound than in the ideal crystal.

There are, indeed, a number of reasons to suspect the existence of such imperfections. The author recently investigated some of them.[4] Here, only one of the most important causes for imperfections is mentioned. This cause is related to the fact that when a crystal grows out of the melt, the heat of fusion is liberated and must be carried off. As this cannot happen infinitely fast, because of the finite heat conductivity of the crystal, a temperature gradient must be established in order to carry away the heat of fusion. This temperature gradient, for actual rates of growth of crystals, is great enough to cause a plastic deformation.

The theory postulating microscopic imperfections meets with some success in explaining a number of structure-sensitive properties of crystals. However, several important considerations may be advanced which show that the "imperfection" theory is far from satisfactory.

OBJECTIONS TO THE "IMPERFECTION" THEORY

In the first place, the growth of crystals can be controlled in many ways. For instance, it would be expected that crystals grown by direct condensation from the vapor phase will not have the same imperfections as crystals grown from the melt. Two specimens grown carefully, but by two different methods, should exhibit vastly different values of their structure-sensitive properties. Actually, this is not the case.

Far more important and conclusive is the following second consideration. If crystals are grown more and more carefully, it would be expected that their various physical properties would approach more and more those which theoretically have been derived for the ideal crystal. In reality, the exact contrary is true. For instance, the better a crystal, the weaker it is. Well purified and carefully grown metal single crystals are extremely soft, as is well known. The same is true of the crystals of the alkali halide group and probably holds in general.

The third argument against the imperfection theory is that it is incomplete, inasmuch as it offers no explanation whatsoever for some of the most fundamental properties of crystals. It does not explain the sharpness of the melting point, it gives no satisfactory account for cold hardening and other peculiar mechanical properties, and it does not provide for an understanding of volume effects.

These reasons induced the author to discard the imperfection theory as inessential and to search for other possibilities of a solution of the problem of the solid state.

COOPERATIVE PHENOMENA IN CRYSTALS

After several attempts, all of which pointed toward the existence of a so-far unsuspected secondary structure, the author believes that he succeeded in reducing the whole problem to the investigation of what he has called "cooperative phenomena" between many atoms or other elementary particles.

First, a few reasons why cooperative phenomena are an essential characteristic of the crystalline state will be given. Then some simple cooperative phenomena which are theoretically manageable will be described, and finally, reasons will be given why cooperative phenomena necessitate the existence of a secondary structure.

A phenomenon, surprising at first, about crystals is that they possess an extremely sharp melting point. From statistical mechanics it follows that melting must take place in the form of a slow dissociation over a great range of temperature if only the interactions between neighboring atoms are considered. Melting in this case would be a process very similar to the dissociation of big gas molecules. A sharp melting point necessarily means that the very existence of crystals is essentially due to the action of some cooperative effects between an enormous number of elementary building stones of the crystal.

A second fact pointing very strongly toward the existence of cooperative phenomena is the surprisingly accurate line-up of the elementary building stones in crystals. For instance, millions of planes in a calcite crystal are lined up within a few seconds of arc over distances as great as one centimeter. It is very difficult to understand this fact on the basis of individual interactions which, as we know, do not act farther than the distance (10^{-8} cm) between two adjacent planes and which are greatly disturbed by the temperature agitation. It is still more difficult to understand why even quite appreciable layers of included foreign atoms do not disturb the line-up.

In the third place, the enormous influence of a few absorbed foreign atoms suggests for its explanation the existence of cooperative phenomena.

Fourthly, volume effects, similar to those obtained in a group of adjoining soap bubbles, are known for quite big crystals. For instance, in a well-annealed polycrystalline metal, the grain boundary between two microcrystals is always concave toward the bigger of the two crystals.

All of these considerations suggest that it will be profitable to undertake a systematic study of the various types of cooperative phenomena and their relation to the problem of the solid state.

Many different types of cooperative phenomena are known in physics. Brief mention will be made of a few. For further details, the reader is referred to the author's article in the *Physical Review*, February 15, 1933.

(*a*) There are cooperative actions which are due to the special types of forces which describe the individual inter-

[4] *Physical Review*, vol. 40 (1932), p. 63.

actions between the elementary particles of the system. For instance, if we investigate the properties of a system consisting of electric charges, such as a space charge of electrons, the mutual potential energy ϵ of two electrons e in the relative distance r is

$$\epsilon = e^2/r$$

The total interaction between a given electron and the rest of the space charge results in a potential energy E of the electron which is

$$E = 4\pi \int \epsilon r^2 \sin \vartheta \, dr \, d\varphi \, d\vartheta$$

Here r, φ, and ϑ are polar coordinates measured from the electron whose potential energy is computed. The integral E depends very essentially on the boundary of the whole system. The pressure at a given point of the space charge, therefore, not only depends on the density and temperature at this point, but also on the geometrical shape of the boundaries of the system. Therefore, it can be said that the behavior of this system in any of its parts depends essentially on the interaction of all the particles which build up the system.

(*b*) Of enormous importance for the physics of crystals are certain phenomena which may be called self-perpetuating magnetic and electric moments of crystals. These are moments which exist even if external magnetic or electric fields are completely absent. Ferromagnetism is a phenomenon of this kind. Ferromagnetism is a cooperative phenomenon because the magnetization process of a given sample depends on its geometrical shape. This shape, indeed, determines the demagnetization factor. Permanent electric moments also exist in certain crystals. The author has shown that they are present in many more crystals than ferromagnetism. The theory suggests especially that the essential cooperative phenomenon in metals is of the type of a permanent electric polarization. Only in a few cases can electric hysteresis phenomena be observed, because of the fact that enormous electric fields must be applied to produce them. In metals, the production of great internal fields is intrinsically impossible, and non-metallic crystals in general break down electrically before the permanent moments begin to line up. For this reason, only very few solid substances are known to exhibit permanent macroscopic electric moments. Rochelle salt, which is such a substance, possesses a permanent electric polarization amounting to approximately 10^7 volts.

(*c*) There are many other cooperative phenomena, such as those related to the so-called exclusion principle in quantum-mechanics, interlocks (*Verhakungen*, in German) of atomic chains investigated by U. Dehlinger, etc. But there is no need here to go into any more details.

THE SECONDARY STRUCTURE OF CRYSTALS

It can be shown that cooperative phenomena are responsible for the very existence of crystals. If no cooperative phenomena were present, the complete transition from the liquid or from the gaseous state into the crystalline state would take place only at the absolute-zero point. The most important conclusion which can be drawn from the presence of cooperative phenomena in crystals is that, in general, they necessarily will cause the formation of a secondary structure.

A secondary structure may be characterized either as a periodic slight variation in density throughout the crystal or as periodically appearing mechanical, electrical, or magnetic stresses. It is not possible to go into any details here concerning the various types, but it is important to give a brief outline of the physical characteristics of secondary structures.

In the presence of a secondary structure, the density, or the specific energy content, etc., must be analytically represented by a triple Fourier series with at least two fundamental periods, one belonging to the primary structure and the other to the secondary structure. The ratio between the two periods may range from about 10 to 1000, in order of magnitude. These estimates are very approximate, as it has not been possible, so far, to develop a satisfactory theoretical method of determining accurately the "secondary" lattice constant.

The secondary structure is the compromise between the individual interactions and the cooperative actions of the atoms during the formation of a crystal. The individual interactions between the atoms of a crystal, or whatever the elementary building stones may be, are responsible for the type of grouping into which the nearest neighbors in a crystal arrange themselves. For instance, in α-iron the so-called elementary cell (which is essentially the grouping of the nearest neighbors) is a cube with an edge of length $a = 2.86 \times 10^{-8}$ cm, whose corners and whose center are occupied by iron atoms. However, the perfection of this grouping is slightly disturbed by the presence of a cooperative phenomenon known as ferromagnetism. The magnetic moments inherent to the electrons (their magnetic spins), indeed, have a natural tendency to line up along one of the three principal axes of the elementary cube. The cube subsequently will be distorted into the shape of a parallelepiped. If the whole crystal were magnetized in one and the same direction, an α-iron crystal would be tetragonal instead of cubic. But the demagnetizing action of the surface prevents a line-up of the magnetic moments throughout the whole crystal. The crystal, therefore, is subdivided into regions which are magnetized along the principal directions of the cube. The sum of the magnetic moments of these elementary regions is zero, so that the crystal as a whole apparently shows no magnetic moment. Such a crystal then possesses a magnetic secondary structure which in two dimensions appears as is shown schematically in Fig. 2.

If d denotes the edge of the elementary cube then, approximately, $D = d/\Delta$, where Δ is the relative distortion caused by magnetostriction. As already mentioned, the theory suggests that metals possess a secondary structure similar to that indicated in Fig. 2, the polarization P being of an electrical nature, however. The deformation of the blocks by electrostriction or magnetostriction would cause the opening of cracks along the π-planes. However, these cracks, during the formation of the crystal, will be filled with extra atoms (at C) so that, in general, we may expect a slightly higher density along the π-planes than about ideal planes.

As in the above example, it can be concluded that the clash for supremacy between the two different symmetry characters of the individual and the cooperative actions of atoms is reconciled in a compromise resulting in the formation of a secondary structure. If the two symmetry characters are accidentally the same, an ideal crystal might be formed. There are several indications that this is the case for diamonds, or at least some diamonds.

EXPERIMENTAL VERIFICATIONS OF THE THEORY OF THE SECONDARY STRUCTURE

Mechanical Properties of Crystals and Solids. The theory of the ideal crystal fails entirely to account for the curious mechanical properties of real crystals and solids in general. The assumption that microscopic imperfections are the cause of this behavior we were compelled to discard likewise. The theory of the secondary structure, however, accounts satisfactorily for the peculiar mechanical behavior of real crystals. How the most important and typical mechanical properties

may be derived in detail from this theory will be the subject of a paper, by the present author, on the plasticity of crystals, which will shortly appear in the *Physical Review*. Here, only a few important points, coming within the scope of the present article, will be touched upon.

It follows, for instance, from the theory of the secondary structure, that gliding essentially takes place only along predetermined planes (π-planes in Fig. 2). Gliding along these planes, according to the theory, sets in for values of the shearing stress which are hundreds or thousands of times smaller

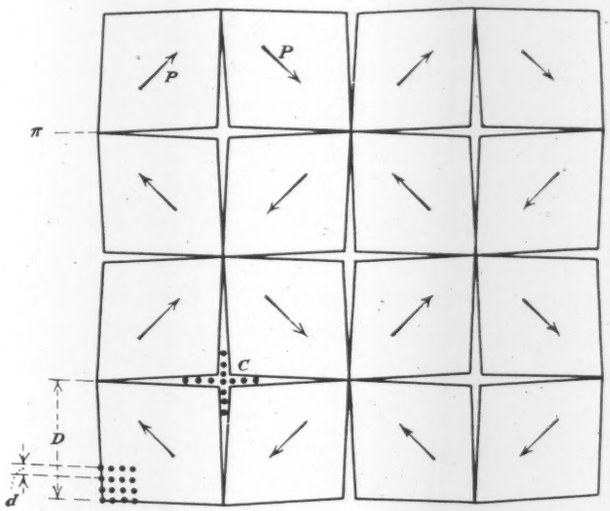


FIG. 2

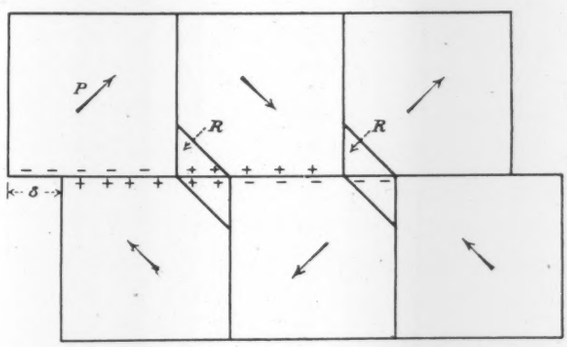


FIG. 3

than those which would be necessary to produce gliding in ideal parts of the crystal. Indeed, the stresses along the π-planes produce along these planes a semi-amorphous arrangement of the atoms which has little resistance to gliding, whose strength against direct rupture, however, may, under certain circumstances, be of the same order of magnitude as that of the ideal crystal.

On deformation, the strength of the crystal against gliding increases, whereas the strength against direct rupture, in general, decreases. This is easily understood for the type of secondary structure shown in Fig. 2. However, the polarization now is electric instead of magnetic.

It is evident from Fig. 3 that the initial displacement disturbs the polarization in adjoining blocks but very little, the disturbed regions being R in Fig. 3. The smallest displacement δ which leads to a plastic deformation is of the order of the lattice constant d. Let us denote with R_{min} the corresponding region in which the polarization P is altered as compared with the initial perfect configuration. Let us see what happens if we deform a crystal in which already large displacements δ have occurred, the disturbed regions being R. If we change δ into $\delta + d$, then the whole region $R \gg R_{min}$ must change its direction of polarization. This much greater rate of storage of electrical energy in the crystal for large values of δ requires increasing shearing stresses if the deformation is to be increased. From the standpoint of the secondary structure, the cold working of metals, therefore, is essentially similar to the process of sliding two sets of alternately charged parallel plates (condenser arrangement) against each other. From Fig. 3 it is also evident that the breaking strength decreases at the same time.

From the theory there follows an interesting relation between

TABLE 2

Crystal System	Substance	H, cal/cm³
Hexagonal	Cd	93
	Zn	163
	Mg	122
Cubic, face-centered	Al	254
	Ag	273
	Au	307
	Cu	365

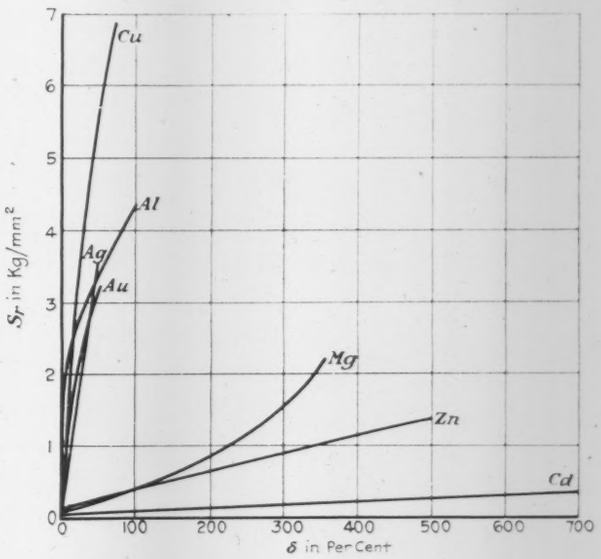


FIG. 4

the heat of fusion of a metal and its tendency to cold hardening. Indeed, according to this theory, the process of fusion is nothing else than the sudden disappearance of that particular cooperative phenomenon, which accounts for the existence of the crystal. In the case of a metal, this phenomenon is probably of the type of an electric polarization P. The heat of fusion H which must be supplied in order to annihilate this electric polarization is therefore approximately equal to the energy of this polarization which is proportional to P^2. The rate of cold hardening, according to the theory, is also proportional to the energy of polarization. Without knowing anything more about the secondary structure of metallic crystals, we can therefore say that the rate of cold hardening must be, for similar crystals, approximately proportional to the heat of fusion. This proportionality holds for the specific strength (per sq cm) and the heat of fusion (per cu cm). This comparison is made in Fig. 4 and Table 2. It is seen from this comparison that for

crystals of the same crystallographic system our expectancy is indeed correct.

It also follows from the theory that the shearing strength at higher temperatures becomes independent of the temperature because this is true for the permanent electric polarization of the crystals.

For the dependency of the shearing strength S on the thickness t of the crystal, this interesting relation is a consequence of the theory of the secondary structure,

$$S = a/t + b$$

The relation between a and b is such that for t approximately equal to 10^{-3} cm, S assumes about twice the value which it has for very large values of t.

Many other important conclusions can be drawn from the theory of the secondary structure with regard to the mechanical behavior of solids. Only a few are mentioned here.

Impurities or small additions of various elements which cannot be built into the crystal (which do not form mixed crystals, properly speaking, with the mother substance), find their natural place in the π-planes which mark the boundaries of the elementary units of the secondary structure. From this one can immediately interpret the peculiar phase diagrams of substances which mix in the solid state but do not form any real mixed crystals. Also, we now can understand the enormous influence of small amounts of various impurities on the structure-sensitive properties of solids. Indeed, a few per cent of added foreign atoms will entirely fill the π-planes throughout the crystal and very essentially influence the effects of any cooperative phenomenon present, which, in turn, determines the structure-sensitive properties. A logical following-up of this line of attack promises to lead to many significant findings of great technical importance.

The theory of the secondary structure also provides for a rational understanding of thermodynamically pseudostable configurations of crystals and solids. These configurations are very important in regard to changes of structure-sensitive properties, such as the mechanical strength on annealing, introduction of contaminations, etc. The possibility of really understanding the processes of annealing, recrystallization, etc., is of the utmost technical importance.

Finally, the following interesting conclusions can be drawn from the theory of the secondary structure:

From the theory and from direct observations, it is found that the dimensions of the elementary cells of the secondary structure in metals are of the order of magnitude $D = 1\mu = 10^{-4}$ cm. This dimension is a critical one, inasmuch as particles of lesser size behave very differently from samples of macroscopic dimensions. It has been found, for instance, that the mechanical and magnetic properties of crystals undergo considerable changes if particles of linear dimensions less than 1μ are investigated. In this connection it may be mentioned that carboloy, an alloy of tungsten carbide with cobalt, becomes harder as the tungsten carbide crystallites which are imbedded in Co become smaller. The maximum hardness seems to be reached if the imbedded crystallites are of the order of 1μ. If alloys containing still smaller particles of tungsten carbide are produced, the hardness again decreases. This points very definitely toward the action of a secondary structure.

Another important case is the waste of matter caused by friction of two solid surfaces against each other, for instance, the grinding in a bearing. If crystals were intrinsically ideal, one atomic layer after the other would be ground off. From the presence of a secondary structure, it follows, however, that entire blocks are torn out of the surfaces of the bearings and that the waste or corrosion in the bearings is much greater than if the microcrystals in the metals involved would be ideal crystallites.

The theory also enables us to understand that a proper surface treatment of a crystal may result in considerable changes of its structure-sensitive properties. Indeed, any cooperative phenomena present in the crystal are greatly influenced by apparently minor and insignificant changes of the surface conditions. Clean-cut experiences on alkali-halide single crystals and on thin glass and quartz fibers fall in line with these expectations. For instance, the strength of a rock-salt crystal can be increased as much as fiftyfold by wetting the surface. Drawn quartz and glass fibers, right after being drawn, exhibit a strength which may be ten times that of an aged fiber. The theory of the secondary structure ascribes this weakening of crystals on drying or aging to the formation of surface cracks and surface inhomogeneities which, if a load is applied, cause premature rupture because of their action of concentrating the stresses. A detailed study of these important phenomena should yield results of great technological interest.

Optical Verifications of the Theory of the Secondary Structure. For the physicist, the most interesting problem is naturally the direct optical verification of the existence of a secondary structure in crystals. If this structure exists, it must be possible to make it visible. However, it may be necessary to apply light of shorter wave length than that to which the eye responds. This will be the case if the characteristic length of the secondary structure D is considerably smaller than the wave length of violet light. Fortunately, a number of cases have been found in which the secondary structure can be resolved by visible light. These secondary structures can be photographed in high-powered microscopes and have been found in crystals of Bi, Cd, Zn, $KClO_3$, and Cu. Structures of the same kind were discovered by F. Bitter for iron, nickel, and cobalt which were investigated while subjected to the action of a magnetic field. In other cases such as LiF, $BaSO_4$, direct evidence of a secondary structure was found by the diffraction patterns of atomic waves (de Broglie waves) and with the help of the ultramicroscope.

The theory also predicts certain definite effects which should be related to the processes of etching and evaporating of crystals. In several cases these predictions were verified experimentally.

Besides a rational understanding of the mechanical properties of the solid state, the theory furnishes much new information about many other physical and chemical properties of solids. A discussion of these properties in this place is not necessary, as they are of less immediate interest to the mechanical engineer.

In conclusion, it may be stated that the theory of the secondary structure, together with the already well-established effects caused by the primary structure, provides for a completely satisfactory frame for all the known physical properties of crystals and solids. Much work, however, is still to be done before our knowledge of the solid state will be established in all of its essential details.

The only way to improve the status of engineers . . . is through their institutions, and it is, therefore, imperative that admission to those bodies should be made more and more difficult; more and more searching. A high standard is far more important than a large membership. . . .Hence, the duty is placed upon them to satisfy themselves completely that their members are of the highest quality and to admit none, whatever the pressure may be, who are not worthy in all respects of that distinction.—*The Engineer*, May 26, 1933, p. 528

GROWTH CURVES

Applications of the Pearl-Reed Population Curve to the Growth of Industrial Production

By WALTER RAUTENSTRAUCH[1]

RECENT publications on economic subjects, particularly those relating to industrial expansion, frequently refer to a "normal growth" and to a "constant rate of increase in productivity." These publications, together with their charts, give wholly erroneous impressions of the nature of industrial growth and hence lead to false conclusions as to future probabilities in industrial activities.

The growth of industry is conditioned by economic factors in the same manner in which the growth of population on a given continental area is conditioned by the physical resources of the area and the rates of their conversion into use forms.

In 1825, Benjamin Gompertz, an insurance statistician, presented a paper before the Royal Society of London entitled, "On the Nature of the Function Expressive of Human Mortality and on a New Mode of Determining the Value of Life Contingencies." The results of his research are expressed by the equation

$$y = ab^{c^t} \quad \text{or} \quad \log y = \log a + c^t \log b$$

in which

y = magnitude of the quantity measured
t = time
a, b, and c are constants

Verhulst, in Belgium, in 1838, derived a formula for the magnitude of population in time having the form

$$y = \frac{K}{1 + ce^{rt}}$$

in which

K = the maximum to which population would attain
c = a constant
e = the base of the Naperian logarithms
r = a constant
t = time

THE PEARL-REED EQUATION

In 1920, Raymond Pearl, of Johns-Hopkins University, in association with Lowell J. Reed, proposed a modification of the Verhulst equation of the form

$$y = \frac{K}{1 + ce^{at} + bt^2 \ldots . nt^n}$$

Other investigators working in different fields have found that the magnitudes of a variety of factors in time have followed the trends indicated by the Pearl-Reed equation. The size of plants and animals in time; the acquisition of knowledge in time, such as the spelling of words; the use of park areas in a given state in time; the production of a given commodity in time; the magnitude of an autocatalytic reaction in time—all these phenomena seem to respond in magnitude in time to the general trend established by the Pearl-Reed equation. Fig 1 shows the magnitude of population in time in the United States (from "Studies in Human Biology," by Raymond Pearl). Fig. 2 records the length of lemon shoots in time (from "The Measurement of Growth," by S. A. Courtis). Fig. 3 gives the amount invested in highways in Connecticut (from a report of the State Park and Forest Commission of Connecticut, October, 1932). Fig. 4 shows the number of registered passenger automobiles in the United States from 1900 to date (from George R. Wadsworth, consulting engineer, New York, N. Y).

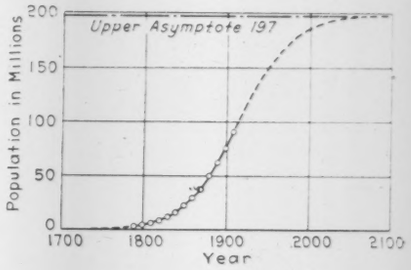


FIG. 1 POPULATION-TIME CURVE FOR THE UNITED STATES

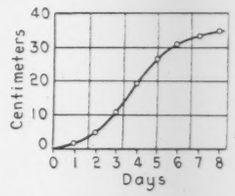


FIG. 2 TREND OF LEMON SHOOTS IN LENGTH

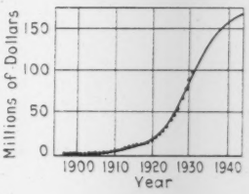


FIG. 3 TREND OF INVESTMENT IN CONNECTICUT STATE HIGHWAYS

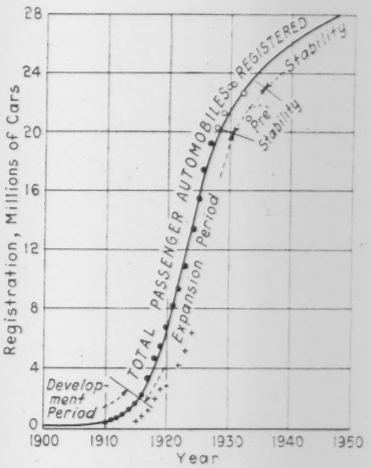


FIG. 4 TREND OF PASSENGER-CAR REGISTRATION IN THE UNITED STATES

The Department of Industrial Engineering of Columbia University is engaged in a study of the growth phenomena of our major industries and finds that these also respond (during the period of expansion), in a general way, to the aforementioned trends.

Fig. 5 shows the number of scheduled air-transport routes in the United States, as plotted by E. Dillon Smith, graduate

[1] Professor of Industrial Engineering, Columbia University, New York, N. Y. Mem. A.S.M.E.

student at Columbia University. The general equation of trend is assumed to be

$$y = \frac{K}{1 + e^{a + bt}}$$

The solution of this equation gives

$$y = \frac{154.953}{1 + e^{3.051 - 0.6423t}}$$

and indicates that the maximum to which scheduled air-transport routes will attain is 155 in about the year 1938, provided the conditions attending the growth so far accomplished are not altered.

Fig. 6 shows the history of the production of bituminous coal in the United States, for which the equation of trend is

$$y = \frac{645{,}418{,}000}{1 + e^{10.0158 - 0.09202t}}$$

where t = years after 1800 (for example, for 1850, $t = 50$). The failure of bituminous coal to respond to the trend after 1922 indicates the difficulties attending the extrapolation of trend curves.

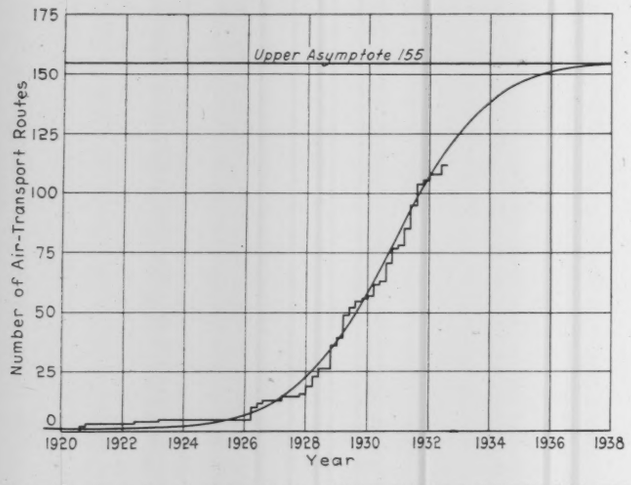


FIG. 5 TREND OF SCHEDULED AIR-TRANSPORT ROUTES IN THE UNITED STATES $y = 154.953/(1 + e^{3.051 - 0.6423t})$

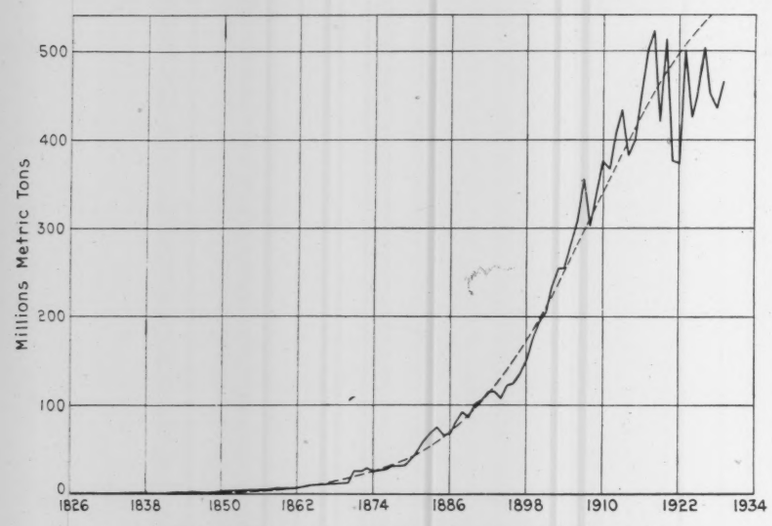


FIG. 6 BITUMINOUS COAL PRODUCTION IN THE UNITED STATES

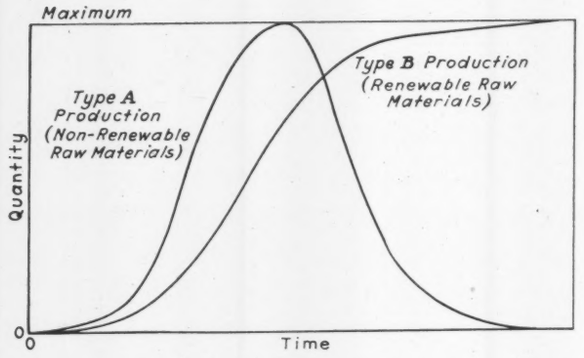


FIG. 7 PRODUCTION CURVES FOR NON-RENEWABLE AND RENEWABLE RAW MATERIALS

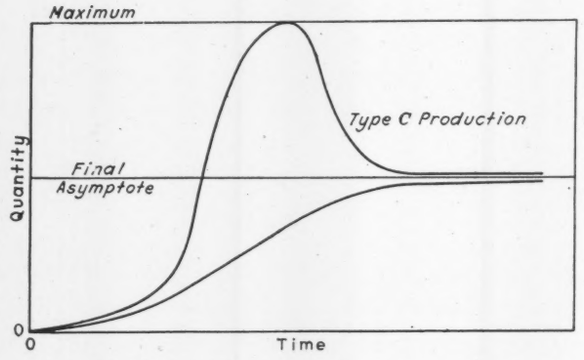


FIG. 8 TREND CURVES FOR MIXED TYPES OF PRODUCTION

TYPICAL PRODUCTION TRENDS

Mr. Bassett Jones, research associate in the Department of Industrial Engineering, Columbia University, suggests that all production in the United States is destined to follow one of three general trends:

(1) Types of production based on non-renewable raw materials (iron, coal, copper) tend to follow a magnitude-time relation as indicated in Fig. 7, curve *A*.

(2) Types of production based on renewable raw materials (water power, crops) tend to follow a magnitude-time relation as indicated in Fig. 7, curve *B*.

(3) Mixed types of production (fabricated goods, electric motors, for example) tend to follow a magnitude-time relation as indicated in Fig. 8, curve *C*.

Magnitude-time relationships when plotted have usually been referred to in economic literature as growth curves. This is an incorrect use of the word "growth" which leads to confusion in analysis and discussion. Growth is the time derivative of magnitude—the time rate of change of quantity. A growth curve, therefore, is a wholly different matter from a magnitude-time or quantity-time curve.

An examination of these magnitude-time curves shows that the growth is changing constantly and that there is no such thing as a "normal" growth in industry. Furthermore, it

will be observed from these curves that the point of maximum growth is the inflection point, the point where the curvature changes from concave to convex. An important point to impress on those who need to be concerned with the future of industrial expansion is that all industries appear to follow these

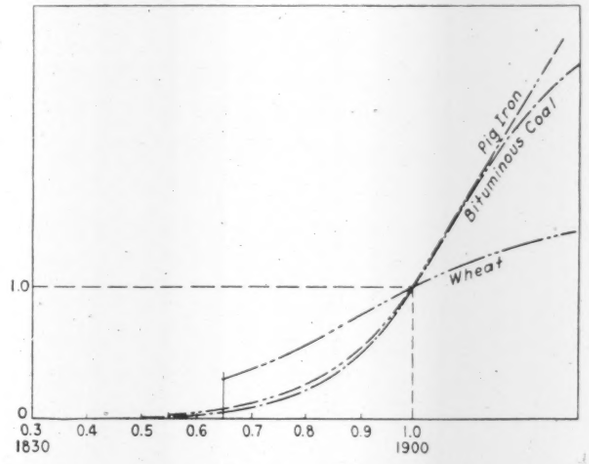


FIG. 9 COMPARISON OF QUANTITY-TIME CURVES OF PIG IRON, BITUMINOUS COAL, AND WHEAT

general trends. Predictions as to a probable maximum of production trend at a future time in a given industry cannot be more than rough approximations, both as to quantity and as to time. Therefore, the determinations of probabilities in both quantity and time by extrapolation based on any fitted curve are of limited usefulness. Furthermore, it is not particularly important. What is important, however, is the rate of change of production in time, that is, the growth. And its importance lies in the fact that the behavior of the capital structure is a function of the growth.

COMPARISON OF QUANTITY-TIME CURVES

Before demonstrating the relationship between the capital structure of an industry and its growth in quantity of production, it will be shown how quantity-time curves may be conveniently compared and how the growth curves may be derived from the quantity-time curves, no matter what particular form the curves of quantity in time may have. No equation of trend need be derived. Both demonstrations to be given are due to Mr. Bassett Jones.

Let it be required to compare the quantity-time curves of bituminous coal, pig iron, and wheat. In each case the quantity-time curve used is the smoothed moving mean of production in time. This comparison is shown in Fig. 9, using the year 1900 as a base time of comparison. Let the span of time 1800 to 1900 be arbitrarily taken as unity. Let any convenient vertical scale be chosen so that unity in quantity will permit the whole range of production to be recorded in the chart. Then, whatever the ordinate to the smoothed moving mean of production of bituminous coal in 1900 happens to be, its magnitude in the chart will be unity. Let this same procedure be followed for both pig iron and wheat. Then the points on each curve will be determined for any year by the ratio of the production of that year to the production for the year 1900. If, for example, the production of a given material for 1900 was 56 million tons and in 1880 it was 10 million tons, the ordinate of the quantity-time curve at 1880 is

$$10/56 = 0.178$$

The general equation expressing the relation of the trend of quantity in time for any production is $Q = t^{f(t)}$ where

Q = the trend of the quantity of production
t = the time corresponding to Q, expressed in convenient units referred to a given base.

This equation expresses the facts observed that quantity varies in time and to an index which is a function of time. For example, if the quantity of production in time is $Q = t^n$, where n may be 2, 3, or 4, or even, say, 3.3, or any other number, then the quantity-time variation will follow a parabolic form. Then a particular curve of a nest of parabolas, such as is shown in Fig. 10, would represent the quantity-time relationship for a particular value of n. It so happens, however, that the observed quantity-time curves lie across this nest of parabolas, as shown in Fig. 10, particularly following the year 1900. Accordingly, then, the quantity of production attained in 1910, for example, is the same *as if* it had followed a given parabolic curve n_1, while the quantity attained in 1920 is the same *as if* it had followed another parabolic curve n_{11}.

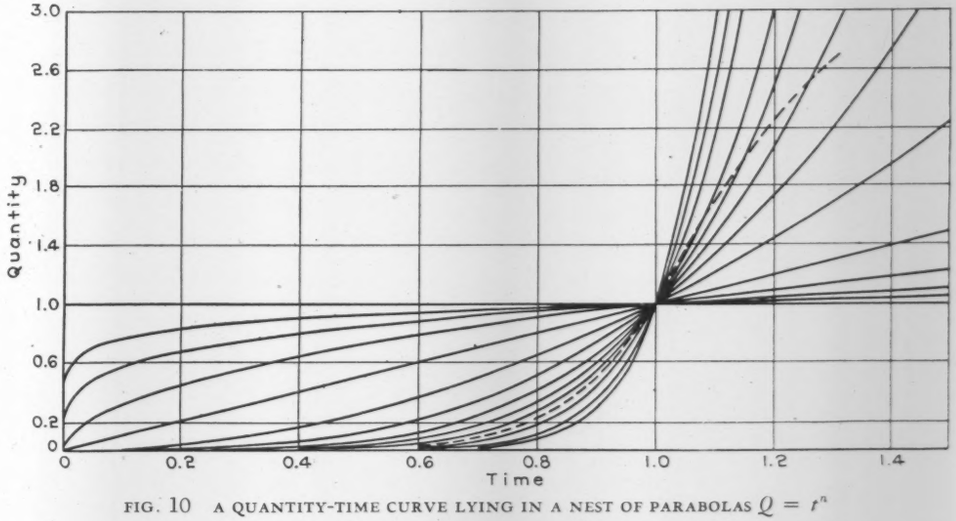


FIG. 10 A QUANTITY-TIME CURVE LYING IN A NEST OF PARABOLAS $Q = t^n$

Accordingly, it appears that, in effect, n itself operates in time as a function of time, and therefore $n = f(t)$.

DETERMINATION OF GROWTH

The growth of production may be found by evaluating the rate of change of Q in time. That is

$$Q = t^{f(t)}$$

$$\text{Then } \log Q = f(t) \log t$$

$$\frac{\log Q}{\log t} = f(t) = n$$

and the growth is

$$\frac{dQ}{dt} = \frac{Q}{t}\left(f(t) + t \log t \frac{d[f(t)]}{dt}\right)$$
$$= \frac{Q}{t}\left(n + t \log t \frac{dn}{dt}\right)$$

The growth at any particular point of the trend curve may be established by this equation in which Q, t, n, and $\log t$ are easily found. The quantity dn/dt is approximated as follows: Let n_1, t_1 and n_2, t_2 (Fig. 11) be intersections of the trend line and the parabolas $Q_1 = t^{n_1}$ and $Q_2 = t^{n_2}$ which occur either side of and close to Q. Then

$$\frac{n_1 - n_2}{t_1 - t_2} = \frac{dn}{dt}$$

which is approximately the rate at which the trend line is changing in terms of n in the neighborhood of Q. Thus there is had a method of analysis of trend curves of production with

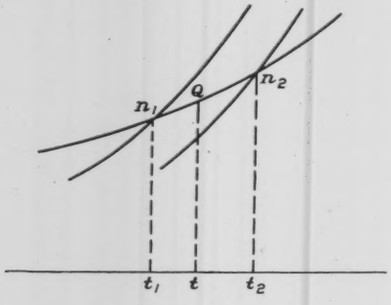


FIG. 11

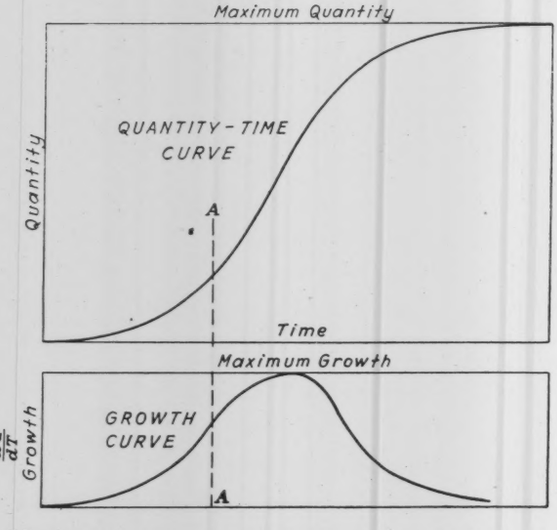


FIG. 12 GENERALIZED QUANTITY-TIME AND GROWTH CURVES

respect of growth which does not depend on an assumed fit such as the Pearl-Reed equation. Such fits, when extrapolated, may depart widely from the real trend. The quantity-time curve for the production of a given commodity is shown in Fig. 12, together with the growth curve of production. It will be apparent from these two curves that the tendency for the quantity to *approach* a maximum is indicated at $A - A$ by the growth curve and that this tendency is not apparent from the quantity-time curve. Accordingly, this analysis provides a means by which the probable trend of production in quantity in time *in the near future* may be anticipated with a reasonable probability.

SECONDARY GROWTH

The trend of industrial production is influenced at times by new inventions and discoveries. The trend of telephone trunk-line construction is a good example. The discovery of the

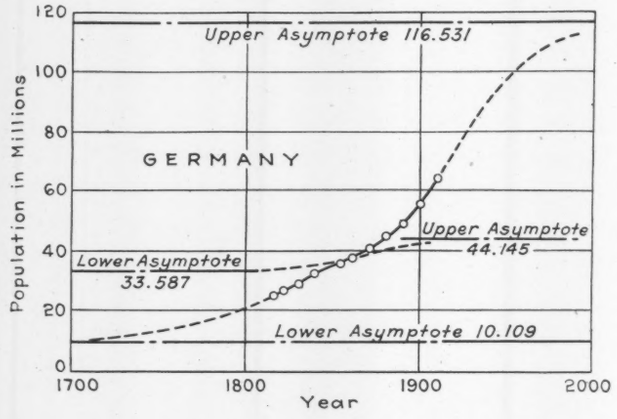


FIG. 13 POPULATION OF GERMANY, SHOWING A SECONDARY INFLUENCE

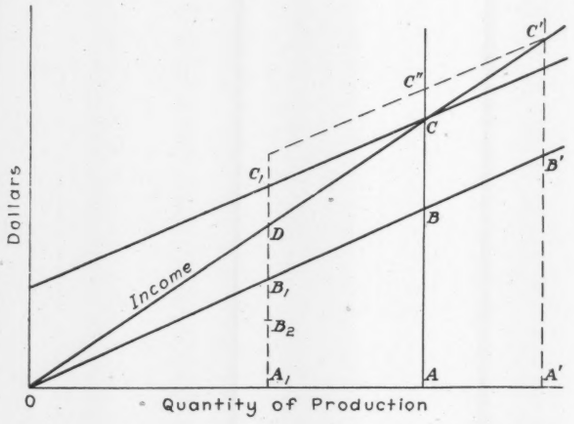


FIG. 14 RELATIVE CLAIMS OF LABOR AND CAPITAL TO THE GOODS PRODUCED

principle of phantom circuits which permitted three lines of communication to be established from a four-wire circuit obviated the necessity of stringing additional wires for a time to care for an increased demand.

Population curves may also be deceptive as to the probable future density of population. Fig. 13 shows the population curve of Germany. In 1820, for example, the extrapolation of the curve would have indicated a maximum population of about 44,000,000 in 1925. About the middle of the century, however, Germany became industrialized and the conditions determining population were altered. Hence, Germany experienced a second growth period in population to a possible maximum of 116,500,000. Japan has also experienced a second growth period in population for the same reason.

Growth curves indicate the probability of trend in the near future and are more sensitive to the effects of changing environment than are trend curves and therefore are more reliable

guides with respect of the immediate future quantity-time relationships.

GROWTH OF PRODUCTION AND THE DEBT STRUCTURE

The importance of the growth of production to the debt structure is determined as follows:

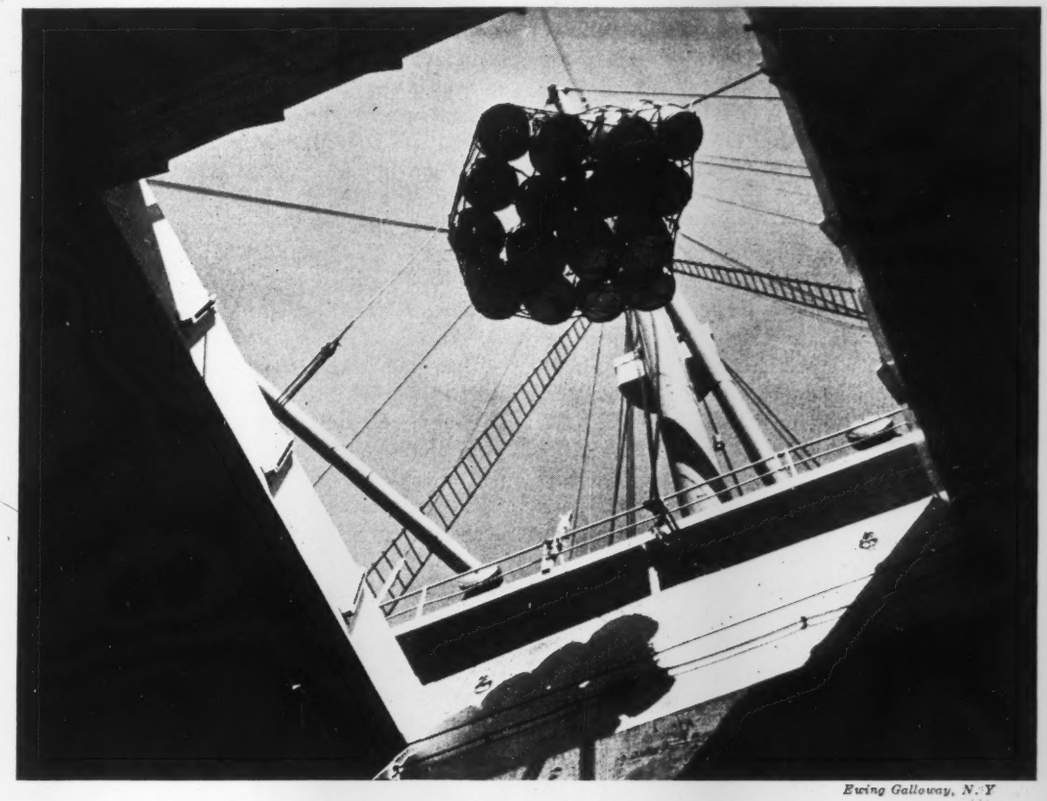
Fig. 14 shows the relative claims of labor and capital to the goods produced.[2] OA represents the quantity of goods produced in a given time. AC is the income from the sale of the goods produced OA, at a constant unit selling price. AB is the share of labor to the income and BC is the share of capital. If the share of capital is increased to a greater amount, it is apparent that production must also be increased; and if the unit selling price and the unit wage remains constant, then for a capital charge of $B'C'$, production must increase to OA'. Thus it appears that increments of increase to capital CC'' must be attended by a proportionate increment of increase to production AA', and for constant units of selling price and wage, the ratio of these increments is a constant. Accordingly, the quantity-time relation of the debt structure (the interest on which constitutes BC and $B'C'$) in industry bears a definite relation to the quantity-time relation of production.

It is interesting to note the consequences of a drop in production to OA_1. In this event, since the capital charges are constant ($BC = B_1C_1$), a balance can be reached between income A_1D and the claims of capital and labor to the income only by a reduction in wages from A_1B_1 to A_1B_2 (where $B_1B_2 = C_1D$). But since the purchasing power necessary to sustain production is reduced by this process, it appears that there is a further tendency to reduce production through a decline in consumer demand. An increase in unit selling price to effect a balance would obviously produce the same result. In consequence of the above relationships, it will be interesting to examine the history of the increase in the debt structure in the United States during the past generation and the history of production during the same period.

Mr. Bassett Jones finds that from 1880 to about 1920 the total debt (internal) of the United States increased approximately at 5 per cent continuous compound interest, while from 1920 to 1929 the increase was at approximately 8 per cent. Total production, however, reached its maximum growth about 1911 and the growth has been declining from that time to date. Apparently, therefore, the accruals to the debt structure from 1911 to 1929 must have been paid out of reserves and these reserves were apparently exhausted in 1929; hence the whole debt structure collapsed. If the above analysis of the relation between the accruals to the debt and the growth of production is correct, it appears that a study of the growth curves of industry is most important, and, furthermore, the maintenance of accruals to debt in proportion to the growth of production is essential to economic stability.

If the credit structure is to be controlled, which apparently it must be if we are to have a reasonably stable economic society, one basis of this control seems to lie in the growth of industrial production. It is not at all unlikely that if the relative claims of capital and labor to the goods produced are maintained in workable proportions by adequate controls of the credit structure to the growth of industry, a second growth may be experienced which may give us an era of well-being of an enduring nature.

[2] See the author's paper, "The Economic Characteristics of the Manufacturing Industries," MECHANICAL ENGINEERING, November, 1932, pp. 759–770.



Ewing Galloway, N. Y

MECHANICAL ENGINEERING

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GEORGE A. STETSON, *Editor*

Industrial Recovery

NOW that the National Industrial Recovery Act has been signed, the advance of business activity under its provisions will be the concern of the entire nation. The time for academic discussion of its fundamental soundness is passed. Making it effective is now everybody's job.

Industry has come a long way on the road of social progress since the Anti-Trust Laws were passed, and its conception of its place in national economic life has been considerably modified. The attitude toward labor is generally more intelligent and more liberal. There exists a growing body of men of the executive and administrative type who are neither owners nor workers, but whose interests lie with both. Upon this group will fall the responsibility of making the new plans successful, for it is this group that will have to make practical application of the new rules of the game. Here is a great opportunity, for success will be another achievement of industrial management.

Unemployment Reserves

IT IS THE easiest thing in the world to express the sincere conviction that honest and faithful employees who are able and willing to work should not be cast out for charitable institutions to support in times of economic stress, but should be afforded some degree of security and protection in the form of payments from unemployment reserve funds. But the problems that are involved in setting up, financing, and administering such reserves are not simple, and few discussions of them are very thorough. We are therefore particularly happy to be able to offer, elsewhere in this issue, Mr. Hook's analysis of this pressing problem.

Readers of MECHANICAL ENGINEERING will recall a previous article by Mr. Hook that appeared in the October, 1931, issue, in which he discussed industry's obligation to the unemployed and described the experience his company had had with unemployment reserves. The present paper, written after two years of increasing economic woes and much personal contact with the far-reaching effects of industrial instability, have given Mr. Hook an opportunity for mature reflection on the practical problems involved in unemployment reserve schemes. His analysis will prove helpful to other executives who have been impressed with the desirability of setting up reserves but who have been perplexed by obvious difficulties.

The State of Matter

MECHANICAL engineers, who started out making use of the most obvious materials in what was almost their natural state, and who knew little or nothing about their inner structures or how they might be modified, have lived to learn that these matters are of extreme importance. Just ahead of them, and sometimes not so far ahead as engineers would wish them to be, are the physicists, the rheologists, the chemists, and the metallurgists, checking theory with experiment and providing more abundant and dependable materials.

While it is not the function of the mechanical engineer to make theoretical studies in the structure of matter, it is greatly to his interest and benefit to learn of the work of others in this field. This makes the presentation of Professor Zwicky's paper in this issue of importance and interest to engineers. Every encouragement should be given to such workers as Professor Zwicky represents in the hope that their studies may be increasingly fruitful of knowledge that will make it possible for engineers to improve materials and use them more understandingly.

An Engineering Job

IN BROOKLYN, N. Y., on one of the surface lines of the B.M.T., there was recently demonstrated a new type of electric trolley car. Scant attention was paid to it in the press, although some of the qualities that the new car possesses—rapid and steady acceleration and noticeably more quiet operation—called for comment, and the fact that certain individuals had sufficient faith in this form of transportation, popularly imagined to be moribund, to expend half a million dollars on its development, was impressive. The car is said to have "gotten away" from a traffic light ahead of an automobile whose youthful driver had been challenged to a test of speed, and the passengers admitted that they were not thrown off their feet by the rapid acceleration. So well had most of the usual noises been eliminated by good design and the use of rubber in construction that the sound of the trolley wheel on the overhead wire was noticeably loud above them.

Ever since the streets of American cities were laid with rails—from the early days of Sprague's first lines, through the heyday of electric interurban transportation that immediately preceded the general acceptance of the passenger automobile and motor bus, to the present with its increasing miles of disused rails and rights of way—riders in street cars have hoped that something would be done to make radical improvements in riding qualities. Heavier rails and heavier rolling stock helped for a while; but the evil days of financial troubles and automobile competition led most to believe that this method of transportation was doomed to disappearance, and the few rattling and track-pounding remnants that persisted would have to be endured until they became inoperable. Cities lost faith and patience, and tore up the rails. It was the day of the bus.

But the demonstration of the new type of car has

called a halt on what appears to be a premature abandonment of the electric car running on tracks in city streets. Engineering research once more promises to restore vitality to an industry that had been given up as lost. And it is this feature of the demonstration on Brooklyn's streets that will interest engineers. At the head of this research and design work for two years has been a well-known mechanical engineer who started with no more knowledge of electric traction than the average man possesses. But he and his colleagues knew how to attack a problem, to analyze its numerous elements, to assemble the data they needed, and to interpret the experimental results. These men knew what they wanted to achieve, and set about to achieve it, adopting what new ideas seemed good, and casting aside traditional designs and methods that had hampered progress in this important transportation agency. This is technological evolution by means of research. It is safe to say that many an industry might be pulled out of a hole by such methods. It is an engineering job.

Flight of Birds

IN THE days before the Wright Brothers, when humanity was looking for a way to achieve flight by any means whatsoever, a very careful study was made of the flight of birds, the conclusion reached being that mere imitation of nature was unpromising, and that other ways of aero levitation would have to be discovered. Accordingly, the double function of the wing, namely, as a means of propulsion and as a means of sustentation, has been split, a revolving member taking over the function of propulsion and planes providing support in the air and in maneuvering.

The problem today is not one of being able to fly, as this has been solved. The question is one of the best and safest method. Here we are still far behind the bird. It is only as our understanding of the aerodynamics of flight, still quite elementary, increases, that we are beginning to approach the methods used by birds. From this point of view it is extremely significant that more and more attention is being paid to the mechanism of bird flight as is indicated by the numerous articles on the subject recently published. One of these has been liberally abstracted in this month's "Survey."

Mechanically, and from the point of view of safety and stability, the human being has been designed in a very unsatisfactory manner. His metacenter is so high as to make his body unstable. His method of propulsion, consisting of jerks, with a constant changing of the center of gravity, is likewise not conducive to dynamic stability. This is well illustrated by the consequences of disarrangements of either the balance mechanism or the motor responses, such as occur in cases of traumas of the balancing mechanism of the ear, or such diseases as locomotor ataxia. Nevertheless, the human being, under ordinary conditions, and with such training as he acquires comparatively rapidly, can walk, run, jump, bend through considerable angles, carry weights, and perform other feats with his body. Here, however, we are dealing not with the original structure, which is unsatisfactory, but with the corrective superstructure, the presence of which is vital in so far as it determines the total performance.

Similarly, it is well to remember that while the wings of a bird, with their presence or lack of emargination, may comprise aerodynamically important factors, the final excellence of flight is also due to the functioning of the bird's brain and balancing mechanism, with its peculiar responses to air currents and its ability to readjust the structure to disturbances in flying.

Nevertheless, from what has already been learned of the mechanism of bird flight, it may be said to be clear that its further study will bring valuable results not otherwise obtainable. After all, if we believe the present teachings of the history of animal life, the bird started as a fish and developed its flying apparatus through what m ght be called experimentation by Dame Nature over a period variously estimated from five to one hundred million years. Not even modern governments would pay for laboratory work equivalent to what it took to make a fish fly in the blue sky.

Reading With a Purpose

TWO implications of the statistics presented in the report on the 1930 Earnings of Mechanical Engineers, published in the latter part of 1931, are recalled by recent statements by Charles F. Kettering to the effect that when a man is 26 years of age he should turn around and look at those younger than himself because at that age there are as many younger than himself as there are older, and, further, that, if at fifty, he cannot learn from the generation at 26, his ideas are already beginning to petrify. The "earnings" report appeared to show that a member of The American Society of Mechanical Engineers, aged, say, 36, will find about an equal number of older and younger fellow members. It further indicated that earning curves, presumably criteria of success, show fairly uniform progress up to age forty but great variation from there on.

In pondering these statements, it seems logical to believe that those who retain their rate of progress beyond age forty do so because they retain the ability of youth to advance, thereby delaying the slowing-down process that comes so easily with the middle years. They are, perhaps, able, as Mr. Kettering suggests, to learn from the younger generation at 26, or, at least, to learn with it.

Combining this thought with the statistical evidence of a preponderant number of young men in the membership of a great engineering society, it seems justifiable to look upon MECHANICAL ENGINEERING as serving those who wish to enlarge their knowledge and wisdom and are willing to expend some effort in doing so. It is our custom to present papers that must be read with a thoughtful purpose. The range of subject matter is broad because the range of interests of engineers is broad. An avid curiosity about developments in engineering and related fields is characteristic of the youthful and progressive minds in the profession.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

AERONAUTICS

The Latest Autogiro

A DEMONSTRATION of the abilities of the latest autogiro—type C30— was given by its inventor, Senor de la Cierva, at the London Airport, Hanworth, England, on April 27, 1933. This new type of machine is a two-seater with dual control and has an Armstrong-Siddeley "Genet" engine. Many modifications have been introduced into its design. Earlier models of the autogiro had auxiliary fixed wings carrying ailerons, but these are not fitted to the new machine, and the inventor has even gone further and shown that a rudder is unnecessary. All control—except that of the engine—is now obtained from a single "stick" moving the rotors and hanging from the pillar on which the rotors revolve. Pushing it forward causes the nose to drop, and pulling it back causes it to rise. Movements to right or left make the machine turn in the corresponding direction. In flight the craft has a top speed of 100 mph, but as it is at low speeds that the advantages of the autogiro construction show up conspicuously, those present were more interested in the demonstration of this quality. As an instance of the small space required for landing and taking off, two tapes were stretched out 50 yards apart, and the machine demonstrated that it could easily land and take off from the space thus set out. Perhaps the best indication of the very slow speed at which the autogiro can fly was given when the passenger lowered a small parcel tied to the end of a string and a man running below untied it and fixed on another which was drawn up into the machine. (*The Engineer*, vol. 155, no. 4034, May 5, 1933, pp. 441, *d*)

Lateral Control in Birds and Airplanes

THE author claims, that a number of recent changes in airplanes may be said to have made them more birdlike. But birds still remain vastly superior to airplanes in respect to slow flight. When a bird is gliding in to land in still air and its forward speed has become so low that the wings, held still, will not provide sufficient lift, a bird can move them forward and go on moving them forward with repeated strokes. In the return strokes, the wings are relaxed, and, being flexible, offer but little resistance to the air. It is probable that in the future, rotating engine-driven wings will reproduce the nearly horizontal flap of birds, which will enable us to fly as slowly as they can.

Rotating wings, however, have certain inherent disadvantages which make it particularly necessary to pay attention to those birds which spend a lot of their flying time in gliding flights. One of the most noticeable things about some of the gliding birds is that they are able to change the incidence of their wings, either together for the purpose of initiating sudden dives and climbs, or in opposition, for putting on bank. This latter attribute deserves attention. To put on bank in airplanes, we change the camber of the wings by pulling up or pushing down a flap at the rear edge, instead of changing the incidence of the wings. Under these conditions, the result is far from desirable, particularly when the wings are at or near the stall. At best, drag is introduced through deflecting the air stream twice, first at the leading edge of the wing, and then at the leading edge of the aileron. The slot in the leading edge of the wing in front of the flap helps, but creates more drag, is expensive, and adds to the weight. Then, because the action of the slot is not perfect, an interceptor is required, incurring still more weight and expense. Judging from birds, this is wrong from the start.

While it may be too difficult to make wings whose incidence can be changed by moving the control column, it does seem

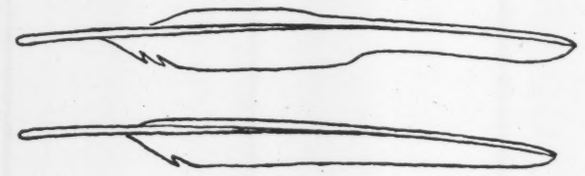


FIG. 1 WING TIP FEATHERS
(Upper feather emarginated; lower not.)

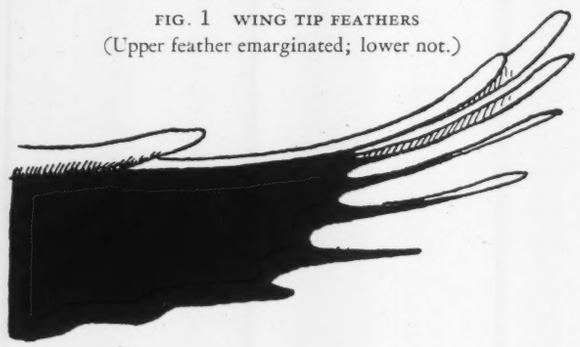


FIG. 2 THE LEFT WING OF A GOLDEN EAGLE IN FLIGHT AS SEEN FROM IN FRONT AND BELOW
(Drawn from a photograph.)

possible for the present to discard the conventional aileron and provide whole-cord wing-tip controllers instead, whose incidence could be changed as easily as that of the ailerons. This would entail some extra weight. On the other hand weight would be saved in eliminating the slot and interceptor, not having to provide strength in the internal construction of the wing to withstand the twisting effect of trailing-edge ailerons, and by the fact that the whole trailing edge of the wing would be available for flaps to be used in conjunction with lift-slots for the purpose of giving high lift at low speeds.

As regards birds, there are two distinct types: those with wings like blades, with feathers closely packed together, such as the gulls and swallows, and those with wings whose feathers separate, such as the rook and eagle. It is from the latter type that one might expect to learn something of value, for these birds are definitely limited in span by practical considerations. Thus, having to live and nest in a rookery, the rook could not possibly get about with wings as long as those of a sea gull.

A comparison of some figures for the rook and the common gull, which are of exactly the same weight, is illuminating. The span of the rook's wings is 32 in. and of the gull's, 44 in., and the mean cord, 5.75 in. for the rook and 3.81 in. for the gull. A short broad wing, such as a rook has, is aerodynamically inefficient, not only for providing lift, but also for lateral control. The rook, however, has been endowed with peculiarly shaped feathers which must help him to a great extent. This shaping of the feathers is called emargination (Fig. 1) which insures that outside a certain point the feathers do not overlap each other. Each feather is therefore free, as far as its flexibility will allow, to have its broader rear web blown upward in such a way that the feather is twisted and its angle of incidence automatically reduced to less than that of the main wing from which it springs. In succession from the front, the feathers are arranged so that the incidence of the first feather is practically nil, that of the second a little more (Fig. 2), and so on, until the rear-most separated feather is almost at the same angle as the main wing. Thus, not only do these feathers act as flexible semi-floating control surfaces, giving lift in addition to control, but they are also unstallable, because each acts as a pre-deflector or slot for the one behind it.

The author believes that any attempt to reproduce this truly wonderful device in the materials which we have at our disposal is out of the question, but a simple form of it might be practicable. Thus, it would probably be feasible to rig a floating whole-cord wing-tip control surface that would provide a certain amount of lift in straight flight, just as the separated feathers of a rook do. This should suffice for the normal sort of wing of fairly high aspect ratio and pointed tip, which is fitted on up-to-date commercial airplanes. Where, as in the rook (and possibly in machines in the Fleet Air Arm), the span is limited by practical considerations and the tip of the wing must be broad, two of these semi-floating controllers might be fitted, one behind the other, each being mounted on the end of a wing-spar, and the rear one being at a greater angle of incidence than the other. (R. R. Graham, in the *Royal Air Force Quarterly*, vol. 4, no. 2, April, 1933, pp. 184–188, 3 figs., *dA*)

AIR ENGINEERING

Performance of Propeller Fans

THIS paper describes a series of tests made necessary by claims published by manufacturers of propeller fans of efficiencies equivalent to from 70 to 100 per cent, and even more. While reliable performance data for centrifugal fans are available, similar data relating to propeller fans are limited, especially in the case of fans of the airplane-propeller type. The present investigation was carried out at the Engineering Experiment Station, The Ohio State University, by Prof. A. I. Brown, as an investigation of the Department of Mechanical Engineering.

The term "propeller" in this investigation was understood to apply to any axial-flow fan, while the term "disk" was applied only to fans in which a disk was a distinctive feature.

The principle of operation of a propeller fan is that when a propeller is rotated about its axis, a difference in pressure is established on the two sides of the blades. Air is drawn into the plane of the propeller on one side from every direction from which it can come without meeting too much obstruction, and is discharged in a jet of one shape or another. A blade of uniform width and pitch will do more work near the tips than near the hub, owing to the higher velocity at the greater radius. In a fan of such design, air is drawn radially toward the part of the blade that is most effective, and the result is a flaring jet of air on the discharge side of the fan; consequently there is little liability of recirculation past the tips. The velocity of the portion of the blade near the hub, however, may be insufficient to overcome the pull toward the inlet side of the fan, and recirculation of air may occur past the propeller near the hub.

It has been found that the performance of propeller fans can be analyzed and recorded in the manner that is commonly applied to the performance of centrifugal fans, and the results appear to be equally consistent.

The results of the tests indicate that the rating of any wall-mounted propeller fan which represents an efficiency of more than 60 per cent, or which, for free-discharge conditions, claims more than 84 per cent of the air capacity of a perfect fan, is most likely incorrect.

When propeller fans are tested for blowing purposes, that is, arranged to discharge into a short duct or collar, greater capacities will usually result than when mounted on a wall. The effect of the collar in increasing the capacity is most pronounced in tests of airplane-propeller fans, especially of designs which apply no means for preventing reverse flow at the tips of the blades.

The power characteristic of fans of the airplane-propeller type is distinctly different from that of the older designs of propeller fans, the power requirement remaining nearly constant for all capacities, or being least at the highest pressures. This feature gives assurance that no amount of obstruction to air flow can cause an overloading of the motor. The pressure characteristics show no sudden breaks such as are frequently found in the performance curves of other types.

The efficiency of airplane-propeller fans is dependent to a considerable degree upon the measure of success in preventing reverse flow at the tips of the blades and upon the avoidance of abrupt changes in the direction of air currents. Fans of this type showed higher efficiencies than were found in the tests of other propeller fans, although the numerical values were lower than those of the thrust efficiencies found in wind-tunnel tests of airplane propellers.

An increase in the number of blades increases the pressure developed by the fan, but with no appreciable effect upon the maximum efficiency.

In the range at or near the free-discharge capacities, well-designed airplane-propeller fans develop higher total efficiencies than are found in this range of the performance of centrifugal fans, although the highest values of total efficiency throughout the range of performance are lower than the maximum values commonly found in tests of well-designed centrifugal fans.

The original article contains a table showing the free-discharge capacities of propeller fans of various power-input when operating at efficiencies from 30 to 100 per cent. In comparing the rating of any fan with the values of this table, it should be noted that some manufacturers catalog their fans upon the diameter of the blade circle, others upon the diameter of the fan opening, and still others upon the overall dimensions. For any values of the diameter of the fan opening other than those shown in the table, at equal power inputs the capacity varies as the 4/3 power of the diameter ratio; and for a fixed diameter of fan opening the capacity varies as the cube root of the ratio of power inputs.

Special attention is called to the section dealing with the reliability of the standard code method of testing. (A. I. Brown, Ohio State University, University Studies, Engineering Series, vol. 2, no. 3, pt. 1, also listed as Engineering Experiment Station Bulletin, no. 77, May, 1933, 33 pp., 12 figs., *e*)

APPLIED MECHANICS (See also Machine Design: Helical Joints in Welded Cylindrical Pressure Vessels)

Spiral Flow of Gases and Liquids

THE advantage of spiral flow of gases and liquids in pipes where a transfer of heat between the fluid and the pipe is required has been well known for a long time, as witnessed by the use of the so-called retarders. This is particularly true where there is a tendency to form deposits on the pipe walls. Such heat-insulating deposits occur in fire-tube boilers (Fig. 3) as accumulations of ash. The author shows, in Figs.

FIG. 3 DIAGRAMMATIC ILLUSTRATION OF THE DEPOSITS OF ASH IN A FIRE-TUBE BOILER

(*Rost* = grate; *feuerbrücke* = bridgewall; *Verlauf d. Rauchgas-Stromung im freien Flammrohr und Enstehen der Flugaschenablagerung* = mechanism of flow of smokestack gases in a fire-tube boiler and formation of fly-ash deposits.)

2 to 8 of the original article, a number of constructions intended to obviate this condition. Of these devices, many tend to produce a spiral flow.

The mechanism of spiral flow as a means of improvement of heat transfer is explained by the author, as follows:

The purpose of all apparatus for the generation of spiral flow lies in lengthening the path of the flow of the given medium, which, in purely axial flow, is equal to the length of the pipe. As the free cross-section of the pipe and the amount of fluid flowing through it remain the same, an increase of velocity is produced. This can take place, however, only by a superposition on the axial flow v_a, of a velocity component v_u at right angles to the axis of flow, by means of which the axial flow is turned into a spiral flow hugging the pipe wall (Fig. 4). The increase in velocity from v_1 to v_2 constitutes a reduction of the free cross-section normal to the direction of flow. Whereas in the case of the device known as *Drallzugspirale* (spiral-flow generator) such a reduction of area in spirally located guiding surfaces does not occur, spaces free from flow are produced and always create losses due to turbulence, as this is the only way in which an increase in the velocity of flow can occur.

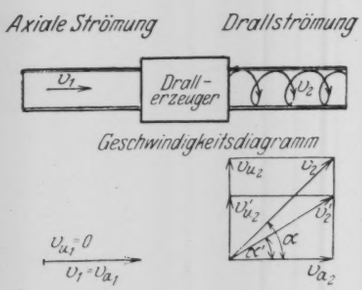


FIG. 4 VELOCITY DIAGRAM OF AXIAL FLOW AND SPIRAL FLOW

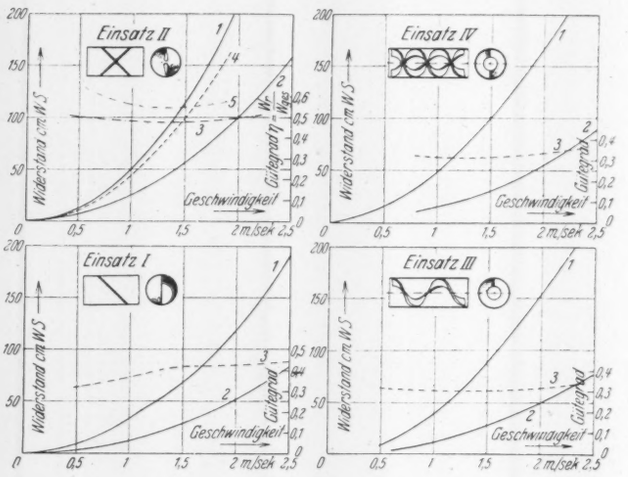
(*Axiale Stromung* = axial flow; *Drallstromung* = spiral flow; *Drallerzeuger* = spiral-flow generator; *Geschwindigkeits-diagramm* = velocity diagram.)

As compared with this method of inserting spiral elements, as is done, for example, in fire-tube boilers, there has developed a tendency to produce spiral flow by the simpler method of providing deflector walls. (Figs. 5 to 8.)

In this case, as opposed to that of spirals, the entire stream is forced through the reduced area formed by the deflector walls and the pipe wall, with an appropriate increase in the velocity of flow. The amount of reduction of cross-section determines the increase in velocity and thereby the increase in the pitch of the spiral.

The inclination of the deflector wall determines the manner in which the increase of velocity takes place. With the deflector walls shown in Figs. 5 and 6, this takes place gradually and automatically, without causing turbulence.

As regards the reduction of draft that always accompanies



FIGS. 5 TO 8 DATA OF TESTS WITH VARIOUS TYPES OF SPIRAL-FLOW GENERATING INSERTS

(*Widerstand cm WS* = Resistance in cm of water; *Einsatz* = insert; *Geschwindigkeit* = velocity; *Gütegrad* $\eta = W_r/W_{ges}$ = coefficient of efficiency. Curve 1: Variation of total resistance W_{ges}; curve 2: Pure flow resistance of spiral flow W_r (wall friction resistance plus additional frictional resistance due to internal turbulence); curve 3: Coefficient of efficiency of the spiral generating insert $\eta = W_r/W_{ges}$; Curves 4 and 5 deal in the case of one insert with deposits on the rear side, such as occur in practice, and show, as compared with curves 1 and 3, an improvement in efficiency. The meaning of W_{ges} is nowhere stated in the original article.)

the application of spiral-flow inserts, the following distinction must be borne in mind:

(1) The reduction of the natural smokestack draft due to the decrease of the temperature of exhaust gases, and (2) the increase of resistance to flow in the tube.

The reduction of draft is of paramount importance in cases where the boiler plant is operated under natural draft. In such cases, it is necessary to investigate most thoroughly whether or not, at the reduced temperature of the exhaust gases, the draft above the grate is still sufficient to maintain the specified steam generation. There are no difficulties, however, with the installation of spiral-flow devices where artificial draft, and particularly suction draft, may be available.

The resistance to flow in the pipes consists (1) of wall-friction loss at the inserted members; (2) of the loss through the creation of turbulence; and (3) of the wall-friction loss due to spiral flow over the remaining free length of the tube. With the same velocity, the first-named component of resistance increases in proportion to the area in contact with the flow. From this point of view, the spiral-flow inserts should be made as small as possible. The second component of resistance is most decidely affected by the shape of the insert, particularly in places where, because of its inertia, the flowing medium cannot follow the stationary guide surfaces, and this gives rise to turbulence.

The resistance to the flow on the free parts of the tube (i.e., parts not equipped with spiral inserts) is obviously greater in

the case of spiral flow than in the case of axial flow, and varies proportionately with the pitch of the spiral.

Since, in the case of a spiral flow, maximum turbulence on the inside of the pipe is directly generated, an increase in the resistance of the tube to the flow of the fluid is unavoidable.

Because of these theoretical considerations, the more modern spiraling inducers in the form of short deflector walls are preferred to the older spiral elements. This is said to be confirmed by some of the data of tests reproduced in Figs. 11 to 14. (Carl Schuster in *Werft Reederei Hafen*, vol. 14, no. 3, Feb. 1, 1933, pp. 36–37, 14 figs., *gc*)

ELECTRICAL ENGINEERING (See Power-Plant Engineering: Electric Steam Generators)

FUELS AND FIRING

Carbonizing Coal in Fuel Oil

DOCTOR GREENSTREET has developed a new kind of low-temperature coal-carbonization process in which the carbonizing is effected on a mixture of coal dust and fuel oil and is carried out in an oil still. The suspension of the fine coal in the oil is made permament by the use of a stabilizer.

By heating the mixture up to 350 C, the volatile constituents of the coal are distilled and the vapors are protected from overheating. It is said that the condensate is particularly free from phenols and other constituents undesirable in the production of motor fuel, and when cracked in the presence of a catalyst, yields a considerably higher output of light spirit than when the fuel oil is cracked. The coal in this process must be pulverized to a fineness which need not be carried beyond 85 per cent passing a 200-mesh screen, or 95 per cent passing through a 100-mesh screen.

About 2 per cent of petroleum soap is used as a stabilizer. The product can be pumped as readily as the fuel oil alone and is fired quite easily.

According to laboratory experience, the boiling point of the coal in oil mixture is considerably below that of the fuel-oil constituent and the percentage distilling over in a given temperature range is likewise greater. A trial on an industrial scale, with a coal and oil mixture with a coal containing 36 per cent volatiles, 50 per cent fixed carbon, 7 per cent water, and 7 per cent ash, and a fuel oil with a boiling point range of approximately 200 to 400 C, yielded from 58 to 60 per cent distillate up to 350 C, of which 44 per cent was derived from the fuel oil and 14 to 16 per cent from the coal. (*The Petroleum Times*, vol. (new) 29, no. 745 (old series no. 1604), April 22, 1933, p. 412, *g*)

HYDRAULICS

The Equation of State of a Real Fluid

THE author has previously shown that on account of molecular attractions the temperature movements of liquid particles are not the same as those of gas particles at the same temperature, and has written the Maxwell-Boltzmann equation in a new form, in which he uses the coefficient λ expressing the ratio of the most probable speed of particles in the liquid to that in a perfect gas. This conception leads to a new definition of temperature which is the mean kinetic energy of a particle of a perfect gas, or the temperature of a thermometer filled with a perfect gas in equilibrium with the substance under observation. If c is the mean kinetic energy velocity of a perfect gas, c_r that of a real fluid, and Θ the temperature, $c_r = \lambda c$, and $\Theta = \frac{1}{2}\frac{mc_r^2}{\lambda^2}$. This definition is said to give for the first time a physical meaning to temperature and an insight into thermal changes. From this, the author derives a dynamical proof of Boyle's law for a perfect gas.

An expression for the expansion pressure of the liquid particles moving across a plane within a real fluid is next obtained. The pressure across the plane is the number of molecules multiplied by their change of momentum. The equation obtained differs from that of van der Waals in containing two essential factors, λ and A, the latter being an association factor. His new equation (*t* in the original article) applies to the interior of the gaseous or liquid phases but is not applicable to the change from liquid to vapor. This equation has also been put into the form of a relation between surface tension and density of a liquid, and an equation of state of a real fluid has been obtained. The equation may be applied to the vapor pressure of liquids. (S. C. Bradford in *Engineering*, vol. 135, no. 3510, Apr. 21, 1933, p. 439, *tm*)

INTERNAL-COMBUSTION ENGINEERING

Rotary-Piston-Type Gas Engines

THIS is the second and concluding section of an abstract of an extensive article dealing with the use of liquids to take the place of the conventional metal piston in internal-combustion engines. The first section of the abstract appeared in MECHANICAL ENGINEERING for June, 1933, pp. 381–383.

There are many who will wonder how it is possible to force a rotating ring of water to make 1000 double strokes per min without breaking up into foam. A consideration of the problem from the point of view of similarity shows, however, that this is possible. Let us say, for example, that a rotary piston machine working on the principle of Fig. 9 has been built to run at 1000 rpm with a stroke of the liquid of 100 mm (3.93 in.). The minimum distance of the level R_i from the axis of rotation is, let us say, 0.25 m (9.84 in.). The eccentricity of the drive $E = 0.035$ m (1.37 in.) and the constant of the drive $\alpha = F/f$ is, let us say, 2. Under these conditions, the individual water level (not considering other factors) runs with the factor of safety $\beta = R_i/\alpha E = 0.25/0.007 \approx 3.5$. This factor of safety is independent of ω. The same safety from splashing will be available with the reduced angular velocity ω_0, at which the centrifugal acceleration acting on the water level is still equal to the acceleration due to gravity, so that $\omega_0 = \sqrt{(g/R_i)}$. The appropriate number of double strokes of the level would be 61 per min, and it appears to be creditable that with 100 mm (3.93 in.) per stroke and 61 rpm of a proper piston drive, there would be no splashing. In the case of rotating cellular wheels, safety from splashing at a given number of strokes of the liquid level is not sufficient to produce a water level free from disturbances. To do this, a further rule of construction has to be followed, to wit:

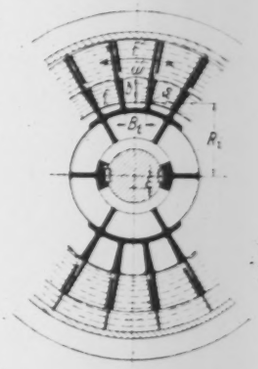


FIG. 9 NOTATION USED IN FORMULAS FOR THE CELLULAR WHEEL OF A "WET" ROTARY-PISTON MACHINE

During the forward and backward oscillations of a water piston between the walls of a cellular wheel, Coriolis[1] accelerations appear and cause the level of the water piston to take a position at an angle to the plane of rotation; that is, cause it periodically to swing out. Moreover, the impulse for such a swinging motion of the water level is a function of the revolutions of the machine. This impulse is repeated at every stroke of the water piston and at every change of the angle with the plane of rotation.

As the level oscillates, so does a certain part of the water piston, which behaves like a water pendulum of unknown length S, which being dependent on the shape of the cell may be expressed as a function of the width of the water level. This water pendulum has a certain definite natural number of oscillations, and if it should happen that the ratio between the period of rotation of the machine and the natural period of oscillation of the water level is such that the impulses of the natural oscillations and the Coriolis oscillations come too fast, one after another, or even coincide with each other within a revolution, then a dangerous resonance might take place, resulting in the rupture of the water surface. Such a rupture would endanger the regular ignition of a machine just as does splashing of the water level when the centrifugal action is improper.

A means of avoiding this danger is based on the law of similarity. If t is the duration of the natural oscillation of the liquid level; σ, a quantity expressing the relationship between the length S and the independent variable B_i, Fig. 9; ω, the angular velocity; T, the duration of one revolution of the machine; and R_i the minimum distance of the water level from the axis of rotation; then the following relations hold good:

$$t = 2\pi\sqrt{\frac{S}{2R_i\omega^2}};\quad T = \frac{2\pi}{\omega};\quad \frac{t}{T} = \sqrt{\frac{S}{2R_i}}$$

which means that the ratio t/T determining the resonance is, for a given design of the machine, entirely independent of its revolutions.

If an individual level of the liquid is sufficiently quiet at the given number of revolutions of the machine, it will be quiet also for all possible numbers of revolutions. Hence, if the number of revolutions is similarly reduced in the case of a model of a single cell, where the actual acceleration due to centrifugal forces present in the machine is replaced by the acceleration due to gravity, then, even when moved back and forth under the acceleration due to gravity, the water level is subject to natural oscillation. Such a test of similarity of a model of a cell carried out with various velocities of drive gives the following expression for the duration of the natural oscillation of water level:

$$t_0 = 2\pi\sqrt{(S/2g)}$$

from which may be derived the value of S, and from $S = \sigma B_i$, the value of σ. The similarity value of the duration of rotation T_0 with the reduced angular velocity, $\omega_0 = \sqrt{g/R_i}$, corresponding to the dimensions of the wheel, is $T_0 = 2\pi/\omega_0 = 2\pi\sqrt{R_i/g}$.

The value of t_0/T_0 must not be equal to unity, but must contain sufficient provision for safety against resonance, corresponding to a constant δ, as yet unknown. If we change the time of rotation of the model drive in accordance with its duration of natural oscillation t_0 until, at a given value t_0/δ, the water level becomes sufficiently quiet, then the ratio δ applies also to the value of t/T in an operating machine, provided the latter is similarly situated with respect to the level of water as the model. From the expression

$$\frac{t}{T} = \sqrt{\frac{S}{2R_i}} = \delta$$

we obtain the value of $R_i = B_i(\sigma/2\delta^2)$. This gives a new rule of construction, determining the ratio between the least level distance R_i from the axis of rotation to the free width of the water level at the inner position of said level. The values of σ and δ are here unknown, but may be determined with a precision sufficient for practical purposes by simple similarity tests.

The above considerations, when applied to the wet-type rotating-piston machine, establish definitely that freedom from splashing and quietness of the water level are independent of the number of revolutions, the internal pressure, and the mass of water.

This lays the foundation for the future development of the wet-type rotary-piston machine, either as a compressor or as an internal-combustion engine, providing the design of the working chambers and the type of drive used for the rotary pistons is suitable for the purpose of the machine.

There are already in existence numerous rotary-piston drives suitable for either dry or wet machines with both internal and external piston drives. (Figs. 9 and 10 in the original article illustrate two such constructions intended for blowers and pumps.)

The author next describes rotary-piston machines with flat valves, the centrifugal forces of which are taken up by roller rings rotating together with the pistons, so that the edges of the valves are very nearly free from pressure and are not exposed to much wear at the walls of the housings. The ordinary method of guiding the rings in the houses cannot be used, however, as they will not stand up with water lubrication.

This construction makes it possible to convert the wet slow-running compressor, which has been described by Riedler, into a rotary machine, retaining the fundamental advantages of water pistons. This machine is capable of producing, in a single stage, the air pressures used in mining and to do its work without internal lubrication, thus completely eliminating the dangers due to the presence of oil vapors in the compressed air. The machine is mounted in a cylindrical housing eccentric to the motor and is provided with ports for the admission and exhaust of gas (Figs. 10 and 11).

The working spaces pass by these ports and no special valve gear is necessary. The rotor consists of a single cellular wheel with radial mutually reinforcing ribs, in the slots of which move steel plates exposed to only moderate bearing pressures and therefore capable of working with water lubrication only. The changes of pressure during the cycle of motion of a valve favors the maintenance of a lubricating layer of water between the plates and their guide surfaces. In grooves in the ribs of the wheel is located, eccentrically to the rotor and centrally with respect to the housing, a roller ring (see Fig. 14) rolling on the surface of the rotor. It bears against the housing wall with only moderate pressure, and takes up the centrifugal forces on all the rotary pistons, so that they glide along the wall of the housing with practically no pressure.

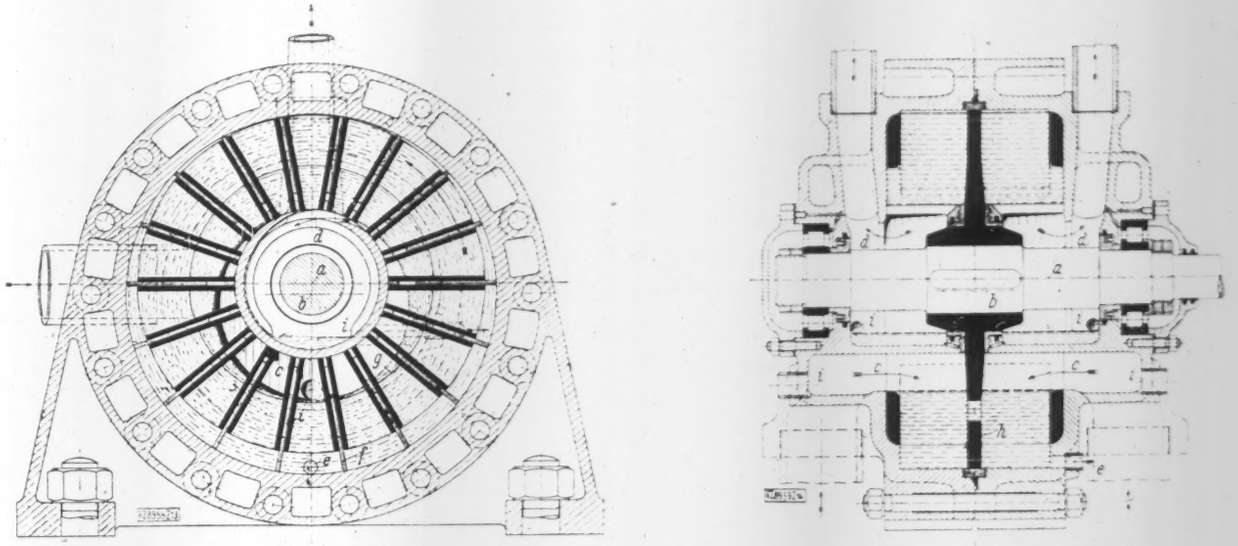
The individual water pistons are located between the rotary pistons, the ribs of the rotor, and the housing. They participate in the rotation of the cellular wheel and are forced by the eccentricity of the housing to execute strokes between the radial cellular ribs. They not only act like compressors, but make

[1] By Coriolis acceleration is meant the double vector product of angular velocity ω of the body of reference times the relative velocity v_r of the point in motion with respect to the body of reference. Where ω is zero, that is, the body of reference is in translation only, the Coriolis acceleration becomes equal to zero.

their entire mass perform the functions of cooling, packing, and lubricating the driving-machinery.

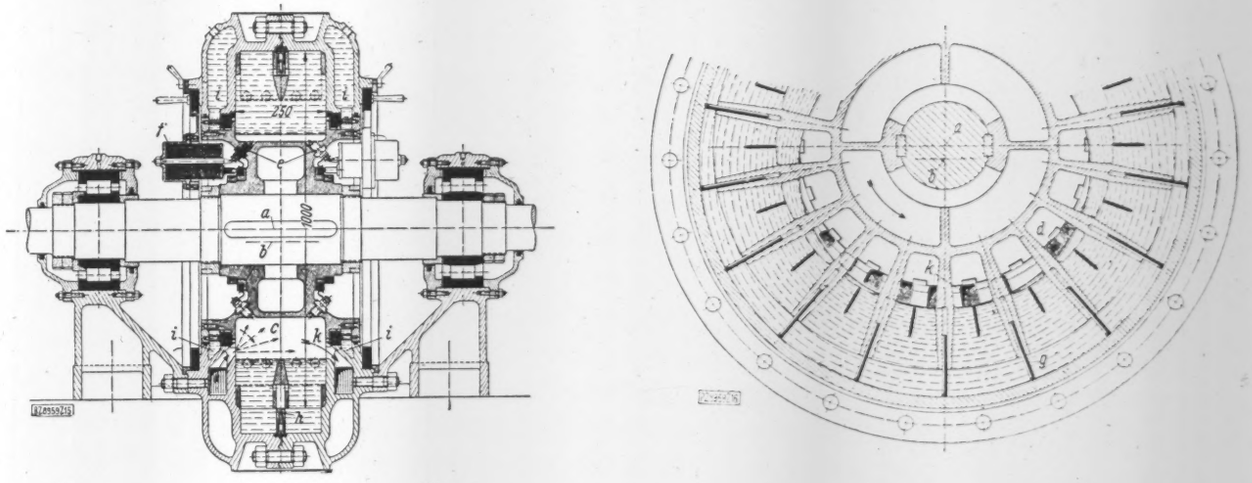
The working spaces, taking in by suction and compressing the air, are located between the water levels and the walls of the housings and rotors. The packing of the edges of the cellular walls is accomplished by individual yielding packing glands for which water lubrication is amply sufficient. When the bleeding of working gases is used to create scavenging air by ejector action, that is, without a waste-heat boiler and steam turbine as intermediaries. The following cycle of operations takes place all the time: bleeding of working gases; ejection of the remaining gases after expansion; exhaust; scavenging; and charging.

As in the case of the compressor, the rotating working cham-



FIGS. 10 AND 11 WET-TYPE ROTARY-PISTON COMPRESSOR WITH PLATE VALVES

(Left, vertical section normal to the axis; Right, longitudinal section; *a* = center line of rotor; *b* = center line of housing; *c* = air inlet; *d* = air exit; *e* = make-up water inlet; *f* = plate valve; *g* = rotor ribs; *h* = roller ring; *i* = overflow port.)



FIGS. 12 AND 13 WET-TYPE ROTARY-PISTON GAS ENGINE

(*a* = center line of rotor; *b* = center line of housing; *c* = scavenging-air inlet, opposite which is located gas outlet *k*; *d* = gas inlet; *e* = spark plug; *f* = break magneto; *g* = valve; *h* = roller ring; *i* = external water seal; *k* = gas outlet.)

compressed air comes out of the valve port, its velocity causes a separation of the excess of water coming out through the same port. Make-up water is always flowing during the suction of the air, no special pump being provided for this purpose.

The rotary-piston machine may be converted into an internal-combustion engine by using the same fundamental rules for determining the dimensional proportions of the drive. The cycle of operation of the wet rotary-piston gas engine corresponds to the conventional two-stroke cycle, except that the bers are located between rigid radial ribs (Figs. 12 and 13) and are automatically controlled as they pass in front of the valve ports in the walls of the housing.

In accordance with the experience gained with the use of the pendulum-ring machine, they are packed against the housing on the cylindrical surfaces within the region of the stroke of the water level, so that the packing elements which have to be used on these surfaces are completely under water at the instant of the highest gas temperature and gas pressure. An

external water seal takes care of the further protection of the packing against high temperatures, and makes it possible to apply packing material with which plain water lubrication is sufficient.

In order not to break up the water level by the stream of scavenging air, the scavenging air is admitted axially from one side of the housing and is present in the form of individual streams having different directions, and covering one after another the various ports of the combustion chamber as shown in Fig. 13. Only a rotary combustion chamber with port control can be so handled. After the working cells have passed by the scavenging and exhaust ports, they are charged with precompressed gas, which, as in the case of a gas burner, is injected in the form of thin individual streams at high velocity. This distribution of the gas and the very powerful turbulence of the mixture produce mechanical mixture of the charge sufficient to insure good combustion.

The ignition of the compressed fuel mixture is certain to be good even if the spark plugs should become wet, as may easily happen at least at starting the engine. Because of this, the ordinary type of spark plugs of a high-voltage, low-current type, easily disturbed by moisture, cannot be used here. Instead, individual make-and-break plugs moving in front of a rigid and powerfully constantly excited electromagnet, are used. The magnet attracts the light contact rods in the plug body and produces on the break an arc of controllable magnitude, even though the plug in the combustion chamber may be short-circuited by a thin bridging film of liquid. It is not necessary to protect the ignition against oil, as in this machine no oil is present.

The make-up of the liquid piston by the addition of cold water takes place continuously, as in the case of the compressor, being supplied at the wall of the housing and particularly in the scavenging zone.

The author discusses briefly the heat consumption and maximum possible output of wet-type rotary-piston gas engines, and presents, for purposes of comparison, indicator diagrams for a two-stroke-cycle Humphrey pump and a rotary piston gas engine, as well as curves showing the indicated output N_i, friction losses N_r, and effective output N_e of a wet-type rotary-piston gas engine, all of these curves being, however, merely computed.

He points out, however, that the loss of heat to the water will be extremely small, and that the wet-type rotary-piston gas engine, when built in large sizes, will not be a fast-moving machine. Further research is necessary to make this machine an engineering success. The author points out, however, that one may say already that the design difficulties which caused the failure of the Vogt water-piston machine have already been overcome when it comes to the wet-type rotary-piston machine. Practical tests have shown its workability over a period of two years. The data of the tests, however, are not published, though it is stated that the builders of the machine will give them out in due time. (*Zeitschrift des Vereines deutscher Ingenieure*, vol. 77, no. 15, Apr. 15, 1933, pp. 393–399, 18 figs., *dA*)

Injection Processes in Compressorless Diesel Engines

THE shape and dimensions of the particles of fuel injected into the compression chamber depend on their surface tension and the forces exerted on the particles by the compressed air.

The surface tension produced by molecular forces may be imagined as being replaced by a pressure equivalent to that caused by an elastic skin around the particle. If S denotes a surface tension uniform throughout and expressed in kilograms per meter, and if ρ_1 and ρ_2 are the radii of curvature of the surface in meters at any point (Fig. 14), then the pressure p_s which produces the given surface tension is

$$p_s = S\left(\frac{1}{\rho_1} + \frac{1}{\rho_2}\right) \text{ kg per sq m} \quad [1]$$

For the case of a sphere with radius r, the pressure is

$$p_s = 2S/r \text{ kg per sq m} \quad [2]$$

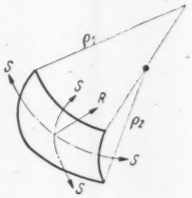


FIG. 14 DIAGRAM OF FORCES ACTING ON AN INJECTED DROPLET OF FUEL (S = constant surface tension; ρ_1 and ρ_2 = radii of curvature; R = resultant stress.)

The pressure p_s is produced by the resultant R of the pressures S applied to the sides of the surface. Should the external pressure p_a be applied to the particle of fuel, an external pressure is produced equal to

$$p_i = p_a + p \quad [3]$$

If the external pressure at any one point of the surface is different, the particle changes its shape. At the places where a higher pressure prevails, a flattening of the surface occurs, so that, according to Equation [1], p_s becomes smaller. The contrary applies to the regions of lower pressure. If the variations of p_s correspond to the variations of p_a, a new state of equilibrium becomes possible, and since the internal pressure in the whole droplet must be the same, the following equation holds good:

$$p_a + p_s = \text{constant} \quad [4]$$

If the external pressure p_a, variable over the surface of the droplet, is of a materially higher order than p_s, the droplet cannot persist. In the opposite case, it can resist an outward pressure by a slight change of shape.

A droplet is exposed to an external pressure variable over its surface when the droplet moves with respect to the ambient air, as, for example, in the case with droplets of fuel in the Diesel engine.

In order to compute the radius of the drops, it is assumed that $p_a = p_s$. This gives

$$r = \text{constant}/w_r^2$$

where w_r is the relative velocity of the droplet with respect to the air. There is a fundamental objection to this equation in that it leads to an impossible conclusion, namely, $r = \infty$ when $w_r = 0$. If, however, this equation is interpreted as providing an expression for the magnitude of a radius of the sphere r that may actually obtain at the velocity w_r, this objection ceases to exist. All that it means, then, is that for $w_r = 0$, in the absence of external forces, an infinitely great sphere may have to be assumed. If, on the other hand, for $w_r > 0$ the radius of the sphere becomes greater than the value determined by the equation, this leads to a collapse of the sphere.

It does not seem correct to assume constant pressure over the surface of the sphere. It may rather be assumed that the distribution of pressure corresponds to a potential flow (Fig. 15).

According to Lorenz, the gage pressure is expressed by

$$\Delta p = \frac{c^2\gamma}{8g}\left(9\frac{z^2}{r^2} - 5\right) \quad [5]$$

where c is the velocity of the sphere; γ, the specific weight of the air; g, the acceleration due to gravity; r, the radius of the sphere; and z, the distance from the center in the direc-

tion of motion of the drop. The sphere cannot withstand this pressure and changes with the external pressure in accordance with Equation [4]. Hence, the following holds good (see Fig. 16):

$$\frac{2}{\rho_A} < \frac{1}{\rho_{B1}} + \frac{1}{\rho_{B2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [6]$$

Thus, for example, if the sphere assumes the shape of an ellipsoid of revolution, Equation [6] holds good under the

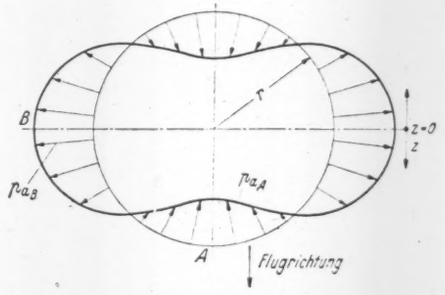


FIG. 15 STRESS ON A SPHERICAL DROPLET OF FUEL WITH A PRESSURE DISTRIBUTION ALONG THE POTENTIAL STREAM

(*Flugrichtung* = direction of motion of droplet; p_{aA} and p_{aB} = external pressures; r = radius of droplet; A, B = directions of axis; z = distance of center of sphere in the direction of motion of the droplet.)

process is repeated with the droplets resulting from this explosion. As the radius decreases, p_s rapidly increases, and finally becomes large enough to cause an equalization of the variations of external pressure by means of small variations of shape. The first break-up of the jet emerging from the

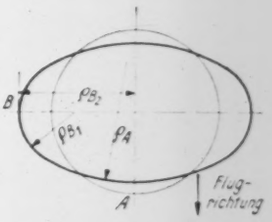
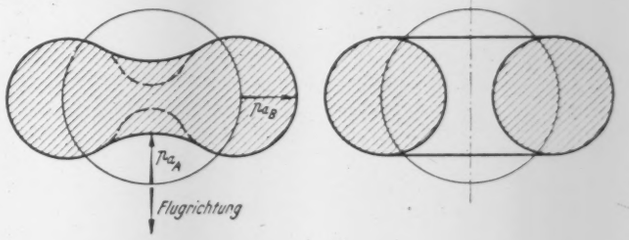
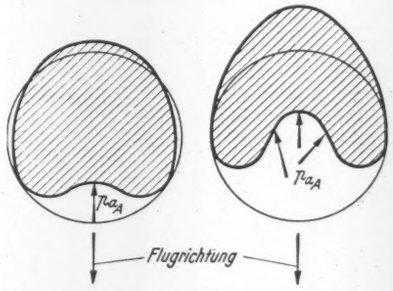


FIG. 16 APPROXIMATE DEFORMATION OF THE SPHERICAL DROPLET OF FUEL UNDER A PRESSURE DISTRIBUTION SUCH AS SHOWN IN FIG. 15

(*Flugrichtung* = direction of motion of droplet; ρ_A, ρ_{B1}, and ρ_{B2} = radii of curvature.)



FIGS. 17 AND 18 PROGRESSIVE STAGES IN THE SHAPE OF THE DROPLET



FIGS. 19 AND 20 CHANGES IN THE SHAPE OF THE DROPLET INCLUDING THOSE DUE TO SUCTION IN THE REAR OF THE DROPLET

(*Flugrichtung* = direction of motion of droplet.)

additional assumption that the volume is constant. It is difficult to make any reliable statement as to the actual shape of the droplet, since the actual pressure distribution differs from the ideal picture of Fig. 15, and varies with the change of shape of the sphere. We are in a position, however, to form a conception as to the probable course of events without going too far into the region of mere hypotheses.

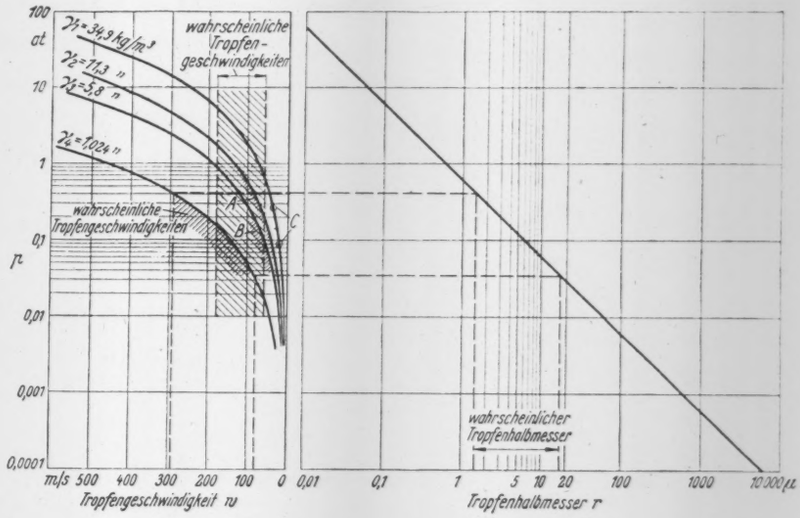


FIG. 21 COMPARISON OF VALUES DERIVED FROM EQUATIONS WITH THOSE OBTAINED EXPERIMENTALLY

(*Wahrscheinliche Tropfengeschwindigkeiten* = probable velocity of droplet; *wahrscheinlicher Tropfenhalbmesser* = probable radius of droplet; *Tropfengeschwindigkeit w* = velocity of droplet w; *Tropfenhalbmesser r* = radius of droplet r.)

If the differences in surface tensions p_s at A and B are not sufficiently large to maintain an equilibrium as against external pressures, the changes of shape go further. Where the flattening takes place at A, there is a recession (Fig. 17) which, in the case of the ideal flow, finally leads to the formation of a ring (Fig. 18); this is increased still further by the increase of pressure p_{aA} at A. The recession at A causes also a lessening of the surface tension with respect to the inner pressure p_i.

Actually, on the rear side of the sphere there is a pressure below atmospheric which causes the sphere to take a shape shown more or less correctly in Figs. 19 and 20. If this change of shape is not sufficient, the sphere bursts apart, and the same nozzle may be due to the same causes, as the forward surface of the jet is also split by the pressure of the air stream.

The following numerical example may help illustrate these phenomena:

Let it be assumed that a droplet of fuel having a surface tension with respect to air of 3×10^{-3} kg per m and a velocity of 30 m per sec is flying through air compressed to 25 atm abs and at a temperature of 755 C abs, which makes the specific weight $\gamma = 11.3$ kg per cu m. According to Equation [5], this produces at A a gage pressure of 0.14 atm and at B a suction of —0.18 atm. If the radius of the sphere is 1 mm, then $p_s = 0.0006$ atm. These external pressures

could not be equalized even by a change in shape such that the radius of curvature at A would be increased a hundredfold and at B correspondingly decreased. The sphere, therefore, cannot help bursting asunder.

On the other hand, if the sphere had a radius equal to 0.0001 mm, then $p_s = 6$ atm, and the sphere is perfectly capable of withstanding differences of pressure much greater than 0.14 and —0.18 atm. As has been stated before, it is difficult to determine the actual changes of pressure and shape taking place, but it is legitimate to state that the sphere does not cease to break up until p_s and p_a become of the same order of magnitude. In the case of injection into a cylinder, p_s and p_a tend to approach each other, p_a becoming small because of the rapid decrease of velocity and p_s tending to increase because of splitting and the general decrease in the size of the droplet.

The above assumptions can be tested by determining whether or not they are in accord with available data of measurement, and for purposes of comparison, the author uses the values given by Fr. Sass in his book, "Kompressorlose Dieselmaschinen," Berlin, 1929. In Fig. 21, p_{aA} or p_s are given as ordinates, while as abscissas are given the radii r, and the velocities w of the droplet. The pressure corresponding to any value of r is found by moving upward to an intersection with the straight oblique line; likewise the air pressure on the droplet at various velocities is found as the intersection of the vertical line with the curve for the corresponding specific weight of air. The following values correspond to given specific weights of air:

$\gamma_1 =$ 1.024 kg per cu m for 760 mm mercury and 20 C
$\gamma_2 =$ 5.80 kg per cu m for air at 5 atm and 20 C
$\gamma_3 =$ 11.3 kg per cu m for air at 25 atm and 482 C or 10 atm and 30 C
$\gamma_4 =$ 35 kg per cu m for air at 30 atm and 20 C

As regards velocities, Sass gives the following values based on tests of the German General Electric Company for an extremely brief instant after injection: 150 to 180 m per sec, then a rapid falling off down to 60 and 70, and finally to about 10 m per sec.

The radius of the droplet is determined by the velocity at the instant at which the droplet is liberated from the jet as the latter is split up and the droplet is exposed to the resistance of the air without the protection of the droplets moving ahead of it. The range of the velocity apparently occurring under these conditions is shown in Fig. 21. It may cover the range between 60 and 180 m per sec. According to Sass, the following dimensions of r prevail for $\gamma = 1.024$ kg per cu m and the following injection pressures: 100 atm, $r = 2.5$ to 17.5μ; 150 atm, $r = 2$ to 15μ; and 200 atm, $r = 1.5$ to 10μ ($1\mu = {}^1/_{1000}$ mm = roughly ${}^1/_{25,000}$ inch). This range is shown in Fig. 21. It corresponds to a velocity of the droplet from 80 to 295 m per sec. The last value appears to be somewhat high, but is apparently within the order of the actual magnitudes found.

The ranges indicated in Fig. 21 as A, B, and C correspond to further experimental values given by Sass. The author claims that this proves that the basis given above for the determination of the functional relationship between the radius of a droplet and its velocity, at least in terms of order of magnitude, gives results in good accordance with those determined experimentally. (Report from the Institute of Internal-Combustion Engineering and Technical Thermodynamics at the Technical High School in Hannover, by O. Klüsener in *Zeitschift des Vereines deutscher Ingenieure*, vol. 77, no. 7, Feb. 18, 1933, pp. 171–172, 8 figs., *et A*)

LUBRICATION

Iron Content in Used Oil as Indicator of the Lubricating Value of the Oil

OFFHAND it would appear that an oil of high lubricating value should produce a smaller wear of the cylinder walls in internal-combustion engines than would a less satisfactory oil. The two oils may yield the same data on general analysis, but it is said to be impossible to determine the "lubricating value" of an oil by laboratory tests. To determine the validity of this assumption, the author carried out tests in which he measured the iron content in oils obtained from automobile crankcases. The tests were made on two Mercedes cars in good condition. The oil was changed after a run of 800 to 900 km, though in one case, a run of 2400 km was made. After draining the crankcase, one half of a full oil charge of a scavenging oil was put in and the cleaning continued for 15 min. The original oil and the scavenging oil were then collected in clean vessels. In neither case were any deposits found; and the amount of iron in the oil was determined by chemical means.

The characteristic features of the oil, such as specific weight, flashpoint, and viscosity at various temperatures, are given in the original article, as well as the amount of iron found in the oil. It was found that the oil which retained considerable viscosity at 100 C showed the least content of iron, while the highest content was shown by an oil which seemed to be particularly affected by heating. The author points out two factors that may have affected the precision of his tests and claims that their influence was immaterial.[2] (Th. Breithaupt in *Petroleum Zeitschrift*, vol. 29, no. 7, Feb. 15, 1933, pp. 6–7 of the supplement, *e*)

MACHINE DESIGN

Helical Joints in Welded Cylindrical Pressure Vessels

IT IS CLAIMED that since the resultant stress to which a helical seam is subjected is less than that which comes on a longitudinal joint, a thinner plate can be used for the same stress or pressure with a consequent reduction in cost of both labor and materials. The author gives two equations for the longitudinal joint, and shows that the stress on a longitudinal seam is twice that on a circumferential seam. He concludes from this that the more nearly we can make the seams in welded cylindrical pressure vessels approach the circumferential in form, the more nearly will the stress on them approach that on a circumferential seam.

The stress on a helical seam is given by the following equation

$$f_r = \sqrt{f_s^2 + f_n^2}$$

or

$$f_r = \sqrt{f_1^2 \sin^2\theta + f_2^2 \cos^2\theta}$$

where f_r is the resultant tensile stress, f_s is the stress along AC (Fig. 22), f_n is the stress normal to AC, and θ is the angle between AC and BC, where BC corresponds to a circumferential seam and AB to the longitudinal seam. From this equation, the tensile stress on the helical seam can be calculated for

[2] In connection with a paper presented before The American Society of Mechanical Engineers, a well-known American industrial concern recently submitted a discussion in which the measurement of metal content in used oils was employed as a means of determining the lubricating value of oils. This discussion has not yet been published.—EDITOR.

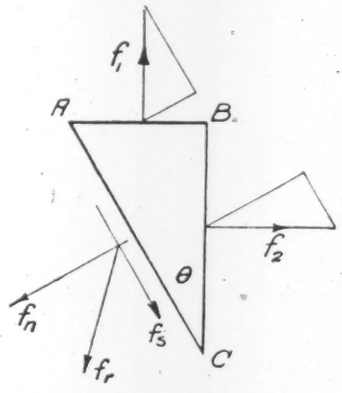


FIG. 22 DIAGRAM OF LONGITUDINAL AND CIRCUMFERENTIAL STRESSES ALONG A HELICAL SEAM IN A CYLINDRICAL VESSEL

various helix angles θ, the original article containing a table of values of f_r for θ equal to 30, 45, 60, and 90 deg, respectively. The variation of the resultant stress on the helical seam with the helix angle θ, which is the inclination of the helical seam to the transverse section, is increased as the resultant stress on the seam increases; hence, from the point of view of reduced stress and the reduced plate thickness that follows, the angle θ should be small. An excessively small angle, however, means a correspondingly long length of seam to be welded, so that ultimately the increased cost of welding will overtake the saving effected on the thinner plate. (G. W. Bird in *Mechanical World and Engineering Record*, vol. 93, no. 2419, May 12, 1933, pp. 454–455, *c*)

POWER-PLANT ENGINEERING (See also Applied Mechanics: Spiral Flow of Gases and Liquids)

Electric Steam Generators

IT IS stated that in the last two years, approximately 360,000 kw of electric steam generations have been placed in operation in Canada and Newfoundland. As evidence of the importance of this electric-steam-generator load to Canadian power companies during the year 1931, the last year for which reports are available, the paper mills alone used about 2,032,000,000 kwhr. By provinces—Quebec, 1,550,000,000 kwhr; Ontario, 320,000,000 kwhr, and 162,000,000 kwhr in the other provinces. The total value of the power so consumed was approximately $2,888,000.

The utilization of peak power for the production and storage of heat has received little attention in Canada, and its economics is discussed in some detail in the original article, where, among other things, it is stated that the investment for a fuel-fired plant is from $2\frac{1}{2}$ to 5 times that for an electric steam generator. (R. W. Leeper, Canadian General Electric Company, Toronto, in *Heat and Power*, April, 1933, pp. 9–12, illustrated, *d*)

Adapting Oil Burners to Pulverized-Coal Boilers

THE conversion of large pulverized-coal-fired boilers equipped with vertical firing equipment to burn fuel oil or pulverized coal without making the conventional installation of turbulent combination burners has not been considered practical by manufacturers of fuel-burning equipment. In view of this situation, the Narragansett Electric Company decided to experiment with vertical firing of fuel oil in its large pulverized-coal-fired boilers. If the experiments proved successful, savings in generation costs could be realized with less differential in prices of coal and fuel oil than had heretofore been possible.

The boilers were equipped with Lopulco furnaces and burners, the burners being installed in a short Detrick arch for vertical firing. One of the purposes of the experimental work was to devise a method whereby fuel oil could be fired through coal-burner openings with low-pressure air, which in this case would eliminate the installation of equipment to obtain air pressure with proper atomization and combustion of oil.

The first mechanical burners were unsuccessful, and so were the steam atomizing burners. Then the mechanical burners were re-designed by the installation of new air ducts from the forced-draft fans to the coal-burner housings, which permitted approximately 70 per cent of the total air required for combustion, including the primary air, to be admitted through burners and burner housings. Flared tips are added to the fantail coal burners to form constricted areas in the air passages, thus obtaining high-velocity air at the point of contact with the oil spray. Holes were cut through each coal burner, through which were inserted the oil-burner barrels. The oil burners were installed in a position to discharge into a path of primary air stream and low enough to prevent impingement of oil spray on the arch and front wall. Sufficient air is allowed to pass through the ports in the refractory walls for protection against overheating. Satisfactory atomization is obtained with an air pressure of 0.5 in. of water in the burner boxes, as compared with five to ten times this pressure required with the conventional type of mechanical oil-burner equipment. Primary air of sufficient quantity is allowed to flow through the fantail coal burners for obtaining proper flame length and to assist in atomization.

The details of the location of oil burners are given in the original article which also gives relative efficiencies obtained with mechanical and steam atomizing burners on similar boilers. The results obtained are said to prove that fuel oil can be burned successfully in furnaces designed for pulverized coal and vertical firing without any changes in furnace design and with only minor changes in the burners. (E. F. Walsh, Test Engr., Narragansett Elec. Co., Providence, R. I., in *Electrical World*, vol. 101, no. 16, Apr. 22, 1933, pp. 522–523, 3 figs., *d*)

SPECIAL PROCESSES

Large Batteries for Electrolytic Generation of Hydrogen

THE author refers to two types of batteries. One is the unipolar type which may be considered obsolete because of the large floor space required and the necessity of using heavy copper bars to connect the terminals of the cells. The more modern type employs the filter-press principle. The large number of electrodes is interconnected by diaphragm frames and constitutes a cell aggregate occupying very little space.

The necessity of producing cells with very large outputs has made it imperative to increase very materially the current density, and this led to a study of means for reducing the cell voltage or the inner resistance of the cell.

The unit shown in Fig. 23 is intended to work with a density of from 500 to 1000 amp per sq m of electrode surface, but has been tested at 3000 amp per sq m. The main electrode *a* carries perforated cathode *c* and anode *d* held to the electrode by bolts. The powerful generation of gases at the auxiliary electrodes keeps the electrolyte in a state of lively circulation which all the time brings new particles of electrolyte into the zone of action.

Bringing the two opposite-pole auxiliary electrodes nearer together effected a considerable reduction of the ohmic resistance. This was assisted by the use of perforated auxiliary

electrodes which permit the gas bubbles immediately after formation to be led toward the rear walls and in this way avoid the region of the flow of ions. The construction of the asbestos diaphragm *e* has been of material assistance in the matter of reduction of resistance. It has been woven in such a manner that although the gases are kept completely separate from each other, no measurable resistance is offered to the motion of the ions. Mere construction methods to keep the potential on the cells low, while maintaining a high current density, are not sufficient. The so-called excessive pressures occurring in the electrolyte cells on the hydrogen electrode are caused by the conversion of the hydrogen from the atomic to the molecular state at the same time that bubbles of hydrogen break off from the surface of the cathode. The character of the surface of the cathode exerts a great influence on the magnitude of the excess voltage, and it would appear that smooth electrodes favor the building up of excess potentials.

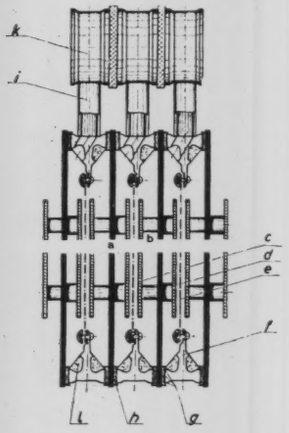


FIG. 23 DIAGRAMMATIC VIEW OF A SECTION OF THE ZDANSKY ELECTROLYTIC HYDROGEN BATTERY

The author has developed a process which produces automatically an increase in the active surface of the cathode within the cell. When a KOH electrolyte of density 1.35 is used, an inverse flow of current, that is, with a cathodic sheet of iron polarized anodically, is employed and maintained until the electrolyte shows violet coloration. This indicates that some of the iron has gone into the solution. The polarity is then reversed and the iron is reduced on the cathode and adheres to the latter in the shape of finely divided metal particles. This method of formation of the cathode has practically completely eliminated excessive voltages and made it possible to employ unusually high current densities with small cell voltages as indicated by curves (Fig. 2 in the original article).

The matter of purity of the hydrogen obtained depends materially on the character of the diaphragm. The gas pressure should be the same in the anode and cathode chamber, as this prevents direct mixture of the gases. By employing specially designed diaphragms, a purity of from 99.9 to 100 per cent has been obtained for hydrogen, and 99.5 to 99.7 for oxygen. The author observed that the purity of both gases, and particularly oxygen, depends on the density of the electrolyte. German costs for a battery to make 5000 cu m of hydrogen per hr are given in the original article. (A. E. Zdansky in *Die Chemische Fabrik*, vol. 6, no. 4, Jan. 25, 1933, pp. 49–51, 4 figs., *dp*)

Formation of Phosgene in Thermal Decomposition of Carbon Tetrachloride

ACCORDING to the Chemical Warfare Service (American University Experiment Station), 25 parts of phosgene per 1,000,000 of air are deadly to man if exposure is prolonged for 30 min. The present investigation would indicate that when carbon tetrachloride is exposed to heat, as is the case when it is used as a fire extinguisher, phosgene may be developed. Such has also been the opinion of the U. S. Bureau of Mines, the Underwriters Laboratories, and foreign investigators. From this it would appear that carbon tetrachloride extinguishers should not be used in a moist atmosphere or in poorly ventilated places, nor should water be applied immediately after. Not only carbon tetrachloride but other chlorinated hydrocarbons decompose under the influence of heat and especially in the presence of metals and moisture with the formation of dangerous gases, of which phosgene is the most important.

At the same time it is pointed out that information as to the actual occurrence of cases of phosgene poisoning from the use of fire extinguishers of this type is scarce. A list of literature cited is appended. (Alice Hamilton, School of Public Health, Harvard University, Boston, Mass., in *Industrial and Engineering Chemistry*, vol. 25, no. 5, Industrial Edition, May, 1933, pp. 539–541, *p*. Attention is called to the discussion by J. C. Olsen, ibid., pp. 541–542, who criticizes some of the statements, not so much in the article here abstracted as in a book published by Dr. Hamilton in 1924. Olsen does not deny that phosgene can form under certain conditions when carbon tetrachloride is used in fire extinguishers, but claims that the quantity so formed is relatively insignificant.)

VARIA

Standardization in Soviet Russia

RUSSIAN standardization is now controlled by decree No. 1928 of June 15, 1932, issued by the Soviet of the People's Commissars. This decree provides that the work of the All-Russia Committee on Standardization is to be concentrated on the establishment of definitive standards for the fundamental engineering and production problems of national economy.

According to a statement by A. K. Gastev, chairman of the All-Russia Committee on Standardization, the work of the committee has suffered in the past from bureaucratic evils. In its desire to have the maximum number of standardization sheets to its credit, the All-Russia Committee has merely summarized and approved the recommendations of sundry industrial organizations without exercising upon them the protective influence for which the committee presumably has been created. On a number of occasions it was discovered that actually the standards had not been adopted or followed in industrial practice and the committee had no time to see that the approved standards were incorporated in practice.

The decree of June 15, 1932, relieves the All-Russia Committee of the preparation of specific standards and relegates this work to the national committees of individual industries, such as the People's Committee of the Lumber Industry, the heavy industries, etc.

The All-Russia Committee on Standardization is now to exercise only a guiding influence on the making and enforcement of standards. The committee will, therefore, become a central research institute on standardization methods, guiding other organizations in the most basic problems of standardization methodology.

The chairman of the committee issued an earnest warning against premature and excessively sweeping standardization of testing methods and manufacturing processes. (I. Gutmann, in *Industrial Standardization*, vol. 4, no. 4, April, 1933, pp. 63–65, *d*)

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer.

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AERONAUTICAL ENGINEERING

The Autogiro Rotor. The rotor of the Autogiro is described, as some authorities have considered that this revolving feature has added much in the way of increased safety and utility to the heavier-than-air craft. In the latest designs the Pitcairn Aircraft blade spars have been made of chrome-molybdenum steel. The necessity of attaining rigidity in torsion has determined in some designs the size of the blade main tubular spar. Research during the year has been devoted to mastering this structural requirement. The chief features are flexibility in the plane of lift, rigidity in the plane of rotation, and rigidity in torsion. (Paper No. AER-54-18, by Heraclio Alfaro.)

Design Problems of Controllable-Pitch Propellers. This paper presents analytical studies of the most common problems that are encountered in the design of mechanisms to rotate airplane-propeller blades about their axes. It includes (1) a brief discussion of centrifugal thrust-bearing loads, (2) an analysis of the torque created by centrifugal force, (3) an analysis of lateral bearing loads from which their frictional torques can be determined, and (4) an investigation of the centrifugal torque of multiple masses by means of which a counterbalance can be designed to neutralize to any desired extent, at all settings, the centrifugal blade torque. The analyses are carried further than in previous published work, and results are reached by which quantitative design data can be obtained with minimum numerical and graphical labor. (Paper No. AER-54-19, by W. B. Heinz.)

Airplane Landing Gears. The landing gear is an important part of an airplane, for although failure may not be as dangerous to life as failure of another part, it is bound to be costly. Five things to look for in a landing gear are strength, satisfactory shock absorption, low drag, light weight, and stable taxying characteristics, and these are not necessarily antagonistic one to another nor difficult of attainment. Landing-gear failures are seemingly more frequent than other failures in spite of high load factors, possibly because taxying loads are neglected in specifying design loads. Small planes are often not able to make use of a retractable chassis, and the one-wheel chassis and tandem-wheel truck are suggested as possible methods of reducing chassis drag. Mention is made of the evolution of the Monocoupe landing gear toward decreased weight and resistance and greater dependability. (Paper No. AER-54-20, by Frederick Knack.)

A Study of Light Signals in Aviation and Navigation. Laboratory experiments have been devised to make measurements of the visibility of light signals under conditions essentially similar to those encountered by the aviator or the navigator. Data have been collected on the direct visibility of flashing-point sources of light of different colors, flash lengths, and intervals, against different backgrounds. The time taken to locate a visible beacon was studied as a function of the beacon intensity and frequency of flashing.

The threshold candlepower required for visibility of a point source against a background is given by an empirical equation. Colored point sources were not found to be useful except in the case of red lights with background intensities above moonlight. For an airplane approaching a beacon it is advantageous to use frequencies of flashing as high as 12 to 30 per min, although with exceptionally clear atmosphere, lower frequencies may be better. In a study of the visibility of flashes of diffused light superimposed on a steady white background, white-light flashes gave the best results. A selective differential photoelectric receiver is described which detects signals of modulated diffused light of low intensity. This sensitivity is independent of the steady background brightness up to 100 times moonlight, and is from 6 to 13,000 times as great as that of the eye in the range of background intensity from darkness up to moonlight. The greatest difficulty in transmission of light signals through fog lies in the loss of advantages of the point source. Dense fog may increase the distances at which diffused-light signals may be detected. The range depends to a considerable extent on the reflectivity of the ground. A theoretical treatment of the diffusion of light through fog, based on the scattering of the light rays by fog particles, indicates that airplanes can be guided through fog at distances of several miles by means of diffused modulated light acting on a differential photoelectric receiver. (Paper No. AER-54-21, by I. Langmuir and W. F. Westendorp.)

Airship Factory and Dock of the Goodyear Zeppelin Corporation. This paper describes the airship factory and dock of the Goodyear Zeppelin Corporation at Akron, Ohio, covering its design and construction, a study of wind pressures, a comparison with other hangars, the docking problem, the design of the doors and the roof covering, with the details of the preparation of the site, the substructure, the structural-steel fabrication and the erection methods employed, the mechanical and the electrical equipment, and the floors, the fire protection, and the helium storage. (Paper No. AER-54-22, by Wilbur J. Watson.)

Racing Propellers for Light Airplanes. To clear up the apparently puzzling situation in regard to propellers for light airplanes with high-speed engines, the author has suggested a design for a racing propeller and then attempted to change its shape systematically in every possible way, noting the effect on the efficiency and the maximum speed. The effect of having the engine deliver its rated power at various revolution speeds is also investigated, as well as running a particular engine at revolution speeds above the rated. (Paper No. AER-54-23, by Fred E. Weick.)

The Design of Practical Light Airplanes. Expense has instilled the thought of low-powered airplanes in the minds of airplane manufacturers during the slump, in order that a market may be maintained for their product and an outlet seed planted for later production. The important features in the design of light airplanes are (1) price, (2) safety, and (3) appearance and performance. The manufacturing cost depends upon materials employed and simplicity of design, and also varies with the quantity produced. Curves are plotted showing the cost of materials and direct labor for different quantities of production. Safety is dependent upon (1) visibility, (2) low take-off and landing speeds, (3) controllability at low speed, and (4) fire hazard. Photos show how visibility is obtained in the pusher type of light airplane. Appearance and performance rank equally in third place, and the author speaks of the necessity for "eye appeal." Performance in light airplanes is not measured in terms of high speed and maneuverability, but should be measured in terms of take-off and landing characteristics, together with controllability at low speeds. Wing-cell

design is discussed, and charts show comparison of wing weights of light airplanes and normal-powered airplanes. (Paper No. AER-54-24, by Karl H. White.)

FUELS AND STEAM POWER

Load-Deflection Relations for Large Plain, Corrugated, and Creased Pipe Bends. This paper presents the results of tests made on 10-in. and 14-in. seamless steel pipe loaded in the same manner as the simple cases shown on pages 526 to 529, "Piping Handbook," by Walker and Crocker. Comparison has been made between calculated deflections and the results of tests in the six cases for a plain pipe bend. The relation between the results of tests on corrugated and creased pipe bends and the calculated results for plain pipe bends of the same dimensions are shown. Such calculations are included as are necessary to show the method of analysis by which the load-deflection relations of a plain quarter-bend and its tangents are determined. (Paper No. FSP-54-12, by E. T. Cope and E. A. Wert.)

High-Pressure Boiler and Turbine Operation at Northeast Station. This paper describes the installation and major problems that came up during $2^1/_2$ years' operation of the high-pressure equipment at the Northeast Station of the Kansas City Power & Light Company. Reheater equipment is discussed, together with the experimental work involved in raising the steam temperature to the desired point, and incidentally obtaining a type of construction that would withstand the high furnace temperatures and give reasonable life. The effect of the reheater troubles on the use obtained from the equipment is also covered.

A general operating history of the turbine is given, dealing in considerable detail with the turbine-blade deposits. Discussion of this phase of the troubles brings out the various changes that have been made in boiler feedwater in an effort to find a relationship between boiler-water concentration and turbine-scale formation. The method used for turbine-scale removal is given.

Only minor troubles were experienced with boilers, high-pressure superheater, and auxiliaries. The effect of continued operation on boiler efficiency has been covered graphically, and the operating performance of the high-pressure equipment as well as the whole station for a typical month has been given showing the heat consumption of the two pressure turbines, the load distribution, and the net result for the station. Considerable detail is given concerning the utility factor of the entire installation and the effect the various individual parts have had on this factor. (Paper No. FSP-54-13, by J. A. Keeth.)

Decomposition of Sodium Carbonate in Steam Boilers. This paper deals quantitatively with the extent of decomposition of sodium carbonate, which is present in many boiler waters and has an important bearing on the inhibition of caustic embrittlement and corrosion. Data are presented in the form of curves obtained from tests on a steaming laboratory boiler at various high pressures and with various feedwaters. The extent of decomposition occurring is found to be dependent upon several factors, the principal one being the amount of sodium carbonate in the feedwater. An attempt is made to correlate laboratory data with those obtained from operating plant boilers. (Paper No. FSP-54-14, by R. F. Larson.)

Radiant-Superheater Developments. Sustained high steam temperatures at all operating ratings, not peak readings at one narrow load range, are being sought in the industry's quest for higher operating efficiencies. Uniform average temperatures, not maximum values, determine commercial economy and even safety of higher steam temperatures. Since premiums are paid for high-temperature equipment on the basis of maximum temperatures, it is important that operating temperatures be uniformly high. Decreasing trends of boiler duty and increasing tendencies of superheater and reheater duty, plus multivalving of turbines, emphasize the inadequacy of purely convection surfaces for maintaining uniform temperatures. A 200-deg F drop in reheated-steam temperature from full load to quarter-load when using only convection surfaces was diminished to 20-deg F decrease in the planning of a recent large 1200-lb, 850-deg F, single-turbine, single-boiler installation, simply by prescribing two-thirds radiant-superheating equipment. Objectives of this paper are:

1 To tell of considerable experiences with radiant superheaters in a station operating many since 1923, showing that their design and operation are based upon sound fundamental principles that have been proved by successful service.

2 To give operating data evaluating the desirable "rising" radiant characteristic at lower loads and to state basic differences of radiant and convection superheaters.

3 To treat the proper applications and to list the incidental merits of radiant superheaters.

4 To treat desirable application of radiant superheaters and reheaters in future large high-temperature, high-pressure, single-boiler, single-turbine installations, illustrating with calculated data based upon experience that essentially constant temperature can be obtained at all ratings.

Experiences in only one station are cited, yet developments of the industry prompting use of all designs of radiant superheaters are treated. (Paper No. FSP-54-14A, by M. K. Drewry.)

Performance of Modern Steam-Generating Units. This paper is based on data collected upon the operation of 244 large steam boilers over a period of three years. A paper was presented at the 1929 Annual Meeting of the A.S.M.E. covering one year's records, but it was thought advisable to continue for at least two years in order to obtain more conclusive results. The primary object was to study boiler outages with special attention given to causes, frequency, and duration, and the effect of such factors as severity of use, design, fuels, and methods of firing on boiler reliability. This paper gives a general summary of the data and a short discussion of results. It will be followed by a more complete analysis of the individual records in the near future. (Paper No. FSP-54-15, by C. F. Hirshfeld and G. U. Moran.)

Influence of Inlet Boxes on the Performance of Induced-Draft Fans. This paper presents experimental results of tests to ascertain the effect of inlet boxes on the performance of induced-draft fans. The tests showed the magnitude of the changes in performance that can be expected and emphasizes the need for testing fans with their inlet boxes attached. The conclusion drawn from the tests is that it is not sufficient for the fan user to know the characteristics of a selected fan with free inlet, but he also should know the characteristics when the inlet box is attached. (Paper No. FSP-54-16, by L. S. Marks and E. A. Winzenburger.)

Solubility of Calcium Salts in Boiler Water. The purpose of this investigation has been to determine the behavior at elevated temperatures of the various chemical compounds found in boiler waters. This includes a study of the solubility of the various compounds under conditions simulating those found in high-pressure boilers. Such a study involves the determination of the solubility of the more insoluble compounds such as calcium carbonate and calcium sulphate separately and combined, as well as in the presence of the more soluble salts such as sodium carbonate, sodium sulphate, and sodium hydroxide. These results should aid materially in determining the proper water treatment for high-pressure-boiler operation. (Paper No. FSP-54-17, by F. G. Straub.)

RAILROADS

Development of Special Rail Equipment. Rail equipment may be roughly divided into standard box, gondola, hopper, flat cars, and other general-purpose equipment supplied to shippers by the carriers. Continued industrial development has necessitated the development of hundreds of special-service cars which cannot be economically supplied by the carriers and must be developed by builders for the use of shippers. This paper indicates in a small way the development of certain interesting types of cars for the transportation of gases, liquids, dry flowing solids, and refrigerated products. The present tendency is toward the continued development of special equipment and ownership of this equipment by shippers, while the carriers confine themselves to supplying general-purpose rail equipment, which is bound to represent the bulk of transportation needs. (Paper by R. C. Pierce.)

A.S.M.E. Boiler Code

Derivation of Revised A.S.M.E. Boiler Code Rules for Reinforcement of Openings

SOME comments have reached members of the Boiler Code Committee that the new rules for the reinforcement of openings in shells and heads, as given in Pars. P-268 and U-59, of the Code, are difficult to understand. In order to assist those who have had this difficulty, the following simplified explanation has been prepared.

Fig. 1*A* and *C* shows nozzles attached by riveting and by fusion welding to the shell of a drum, and *B* and *D* the same nozzles with parts of the cross-sections marked in different ways for use in the explanation.

Pars. P-268*b*(1) and U-59*b*(1) state in effect that the area of the hole to be reinforced is the diameter of the opening plus the diameter of the rivet holes, if any, measured at the weakest section, minus 2 in., multiplied by the thickness of shell plate as calculated by Pars. P-180 and U-20, using $E = 0.90$. Also, that the amount of reinforcement, deducting for rivet holes, if any, must be equal to that area, with the stipulation that no parts outside of the rectangle *ABCD* may be computed as reinforcement. The limits of this rectangle are (1) *AD* and *BC*, which are located each side of the center line of the opening a distance equal to the actual inside diameter *d* of the opening, (2) *AB* and *CD* which are located 3 times the actual plate thickness above and below the middle line of the actual shell plate thickness.

In the case of nozzles, that portion of the walls to a height of $2^1/_2$ times the wall thickness *n* above the surface only may be used as reinforcement.

Within the limits of the rectangle *ABCD*, the excess thickness of the shell plate, deducting for rivet holes, if any, above that determined by Pars. P-180 and U-20 for $E = 0.90$, as above stated, may be included as reinforcement.

When two openings are close together so that the limiting rectangles normally would overlap, the limit lines between the openings must be adjusted so that no overlapping occurs, since reinforcement can be applied to no more than one opening.

These rules are substantially what was required by those now obsolete in the 1931 Combined Edition of the Boiler Code, but are more explicit as to details of calculation.

The reason that the efficiency *E* is taken as 0.90 is to make the revised rules conform with the old and well-established rules for reinforcement of steam domes and manholes. The reason for deducting 2 in. from the diameter of the opening in determining the area to be reinforced was to permit the use of many types of small openings which experience has shown to be safe, such as hydraulic couplings welded into thin shells and welding necks without reinforcing pads.

Fig. 1 gives simple illustrations of riveted and welded nozzles lettered to show the application of these latest A.S.M.E. rules for openings of the reinforced type.

The several designations are defined as follows:

Lines *AB* and *CD* = extreme upper and lower limits of reinforcement

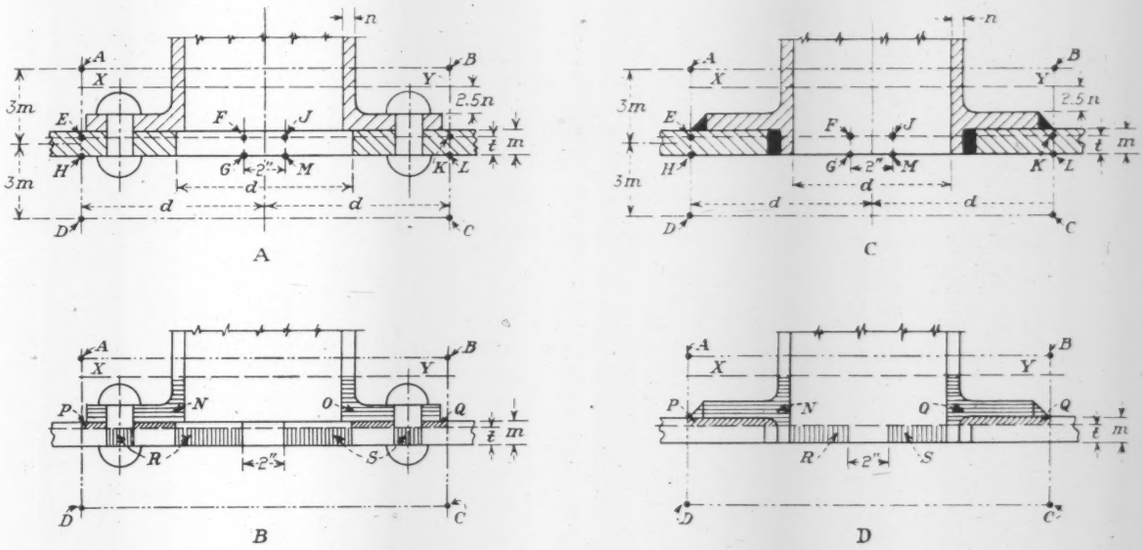

FIG. 1

Lines *AD* and *BC* = extreme side limits of reinforcement

Line *XY* = extreme height of walls of nozzle that may be computed as reinforcement

m = actual thickness of shell plate

t = required thickness of shell plate as determined by Pars. P-180 and U-20 with $E = 0.90$

n = thickness of wall of nozzle

d = diameter of opening

Areas *N* and *O*, Fig. 1*B* and *D* (horizontally shaded parts) = attached reinforcement

Areas *P* and *Q*, Fig. 1*B* and *D* (oblique-line shaded parts) = excess shell thickness considered as reinforcement

Areas *R* and *S*, Fig. 1*B* and *D* (vertically shaded parts) = area to be reinforced.

When expressed as formulas, we have

$$N + O + P + Q \geqq R + S$$

By comparing the cross-sectioned areas in Fig. 1*B* and *D* with Fig. 1*A* and *C* it will be found that the amount of reinforcement required is the same as by the A.S.M.E. Rule, as illustrated in Fig. 1*A* and *C*, where the cross-sectioned areas within the rectangle *ABCD* which come below the line *XY*

must be at least equal to or greater than the sum of the areas *EFGH* and *JKLM*.

It will be seen on examining the diagrams that the diameter *d* of the opening for a riveted nozzle is the diameter of the opening in the shell, whereas the diameter *d* for a fusion-welded nozzle is the diameter measured inside of the nozzle opening. The reason that the diameter is measured on the inside of the nozzle opening in the case of a fusion-welded nozzle is that the strength of the fusion welds makes it necessary to reinforce only the opening that is inside of the nozzle.

For riveted nozzles where the rivet holes straddle the center line of the opening, the section is taken through the rivet holes nearest the center line and the dimensions used in the calculation are those in this plane, except that the limit lines are defined by the diameter of the opening in the shell at the center line of the opening and the actual wall thickness of the shell or the nozzle.

It is not required that the means of attachment shall lie within the limit lines. For instance, in many riveted nozzles, especially those of small diameter, it is manifestly impossible to locate the rivets within a distance of one diameter from the center line of the opening. In such cases, the rivets are credited with their full shearing strength, regardless of their location with respect to the limit lines, but only those rivet holes or parts of rivet holes lying within the limit lines are considered when determining the area of the hole to be reinforced and when computing the reinforcement either in the nozzle flange or in the excess shell thickness.

Another feature to be investigated in the case of riveted connections is the possibility of failure of the shell plate by tearing around through the rivet holes. This may be checked by the method given in Par. P-193*c*.

Any excess thickness provided for corrosion should be deducted before applying the rules for reinforcement of openings.

Power Test Codes

Linear Measurements

A MONOGRAPH on "Linear Measurements," Part 14 of Power Test Codes, "Instruments and Apparatus," has just been completed, and is about to be presented to the A.S.M.E. Committee on Power Test Codes and the Council for approval. Before taking this step, however, the Committee is calling it to the attention of the public in general. Copies of this material are available to those interested, and may be obtained on application to the headquarters of the Society. The Committee and the Society will welcome suggestions for corrections and additions to this draft report. These comments should be addressed to C. F. Hirshfeld, care of the A.S.M.E., 29 West 39th Street, New York, N. Y.

The several sections deal with calipers and dividers, tapes, rules and scales, vernier calipers, micrometer calipers, dial gages, and thickness gages.

The selection of an instrument for a linear measurement depends on the particular measurement to be made and the degree of accuracy desired. While the measurement of length is subject to variations depending upon temperature, the correction is so small that in the majority of cases it may be neglected. For instance, in measurements with a steel tape or scale, a change of about 150 F is required to produce an error of 0.1 per cent. However, in the measurement of long distances by steel tapes, to secure extreme accuracy, it is necessary to apply a correction factor for the thermal expansion or contraction, except with Invar steel tapes.

The committee in charge of this part of the Power Test Codes activity consists of C. F. Hirshfeld, chairman, W. A. Carter, secretary, C. M. Allen, E. G. Bailey, L. J. Briggs, C. R. Cary, J. D. Davis, R. E. Dillon, F. M. Farmer, J. B. Grumbein, W. H. Kenerson, E. S. Lee, E. L. Lindseth, O. Monnett, S. A. Moss, E. B. Ricketts, and W. A. Sloan.

CORRESPONDENCE

Balancing of Economic Forces

TO THE EDITOR:

"Hamlet with Hamlet left out" is the only way to describe the summary of my plan as it appeared in your May issue.[1] I must accept the onus for the inadequacy of that summary, inasmuch as I was given a chance to review it before publication. But somehow I failed to notice that it omitted almost entirely to mention the central distinguishing feature of my plan.

The plan is designed to provide a permanent adjustment for balancing productive capacity with consumer's demand. It provides a pump whereby purchasing power in any desired volume may be diverted from the creation of productive facilities to the raising of our national standard of living so as to consume the products of industry.

This pump is in two parts: (*a*) a more effective income tax (with a suggestion of how the yield may be doubled without exceeding the present maximum rates but allowing liberal personal exemptions) to put a brake on the mechanization of industry; and (*b*) "prosperity pensions" to distribute purchasing power to consumers. By "prosperity pensions" is meant pensions to every man and woman who proves a specified age and American citizenship, regardless of income or property or ability to work.

The income-tax feature is found in several of the other plans, and differs only in the suggestion of a better method for stopping the present leakages of revenue; but the idea of prosperity pensions is the distinctive feature of this plan. Prosperity pensions are proposed as the best method of putting purchasing power into the hands of consumers for the following reasons:

(*a*) They would reach every corner of the country equally and fairly.

(*b*) They offer less opportunity for corruption than any other method of disbursing billions.

(*c*) They would not interfere with or compete with any industry.

(*d*) They can start moderately, but can be increased in-

[1] See MECHANICAL ENGINEERING, May, 1933, p. 301, "Plan of John Willard Roberts," one of the 23 plans analyzed by the American Engineering Council's Committee on the Relation of Consumption, Production, and Distribution.

definitely, so as to divert any volume necessary to keep mechanization and consumption in balance.

(*e*) They can be continued indefinitely so that business will not worry over the effects of termination.

(*f*) They are not subject to engineering halts and delays.

(*g*) When overmechanization again threatens, they can be increased immediately, warding off depression before the vicious circle gets started.

(*h*) Prosperity pensions would reduce the need, now too desperate, for savings and investment, and would thereby set in motion an auxiliary pump by enabling people before pension age to save less and spend more. This would multiply the effectiveness of the prosperity pensions themselves and the income tax, so that the total diversion of purchasing power from mechanization to consumption might be many times the amount of money handled by the government.

(*i*) By this balancing of production and consumption the price level can be stabilized, thus removing the quicksand on which all currency and banking have hitherto been founded.

JOHN WILLARD ROBERTS.

Mamaroneck, N. Y.

Future Design of Passenger Equipment

TO THE EDITOR:

Mr. Barba's analysis of the future design of passenger equipment[2] is of particular interest to an automotive engineer. The constructions and principles which have made automotive, vehicles successful are at last being recognized as applicable not only to railway practices but as an essential phase in the solution of present railway problems.

Automotive vehicles have been made possible only by light-weight construction. Two essential factors have contributed to the accomplishment of light weight, the use of structural materials of the highest quality and lightest weight, and the effective cushioning of road shocks by means of pneumatic tires.

The subject of high-quality steels as an essential construction material for the railway car of the future has been covered in Mr. Barba's paper but I feel it appropriate to add some remarks regarding the effect which pneumatic tires are bound to have upon future railway-car designs.

Any one who has had occasion to ride in a pneumatic-tired rail car will readily admit that for riding comfort and silence, it has the most luxurious automobile or aircraft beaten to a standstill. The pneumatic-tired rail car seems to offer an effective method of fighting the competition of the road bus, especially if one- or two-car light-weight rail-car trains, operating at frequent intervals, are substituted for long trains.

One pneumatic-tired rail-car type was pioneered in France but its present high development was accomplished in this country, especially the use of welded stainless-steel sections for the under-structure, which has resulted in considerable reduction in car weight. Weights of about 470 lb per passenger have been attained for such a rail car seating 47 passengers. The pneumatic tires with this type of rail car run directly on the tracks and appear, therefore, to be limited in carrying capacity and subject to considerable wear. This relatively limited load-carrying capacity of the pneumatic tire under such conditions is indicated by the necessity of using a considerable number of axles, six in the above-mentioned car, in order to distribute the load.

A highly practical solution seems to have been developed in Austria. Here each pneumatic tire rolls inside its own circular steel track, which in turn rolls with its steel rim of standard railway profile on the railroad track.

All vertical loads are absorbed through the pneumatic tires, which at the same time cushion all side shocks transmitted to them by the steel track wheels. These steel track wheels are mounted upon separate floating axles, which have no direct connection to the frame, and therefore none of the rail shocks are transmitted to the frame. The pneumatic-tired track wheels are mounted in pairs on automotive-type axles, which in turn are attached to the frame by flat leaf springs.

The service results obtained seem to indicate that pneumatic tires operating in this manner have twice the load-carrying capacity of the same tire when running on a highway. The pneumatic tire is free to expand inside its steel track and, owing to freedom from chafing and abrasion, tire life should be greatly in excess of that of a tire operating on a highway or on a railroad track. With this method of mounting pneumatic tires, the braking problem has also been simplified, since there is no rubber tire surface in contact with the track. Furthermore, with the brake drum mounted on the steel track wheel, the brake heat is fully dissipated before reaching the rubber tire.

Up to the present time the development of this pneumatic suspension has been in the form of light rail cars called the "rail-bus." This rail-bus carries 32 passengers and has a maximum speed of 62 mph. The net weight of the car, 13,200 lb, or 412 lb per passenger, has been obtained without the use of welded stainless-steel shapes, and it stands to reason that further weight reduction should be possible with the use of stainless steel.

G. A. UNGAR.[3]

New York, N. Y.

The Problem of Economic Balance

TO THE EDITOR:

The article by Sumner H. Slichter in the February issue of MECHANICAL ENGINEERING, "The Problem of Economic Balance," contains much to commend, especially the conclusions as to the unbalancing effect of credit. However, I wish to take exception to the author's discrediting of the "lack-of-purchasing-power" theory of business cycles. His presentation of the theory is good, but he does not justify his statement that lack of purchasing power is a result of depressions. The lack of purchasing power has been just as much in evidence during prosperous years as during depressions. During all periods of so-called prosperity the workers have been obliged to produce approximately twice what they, with their limited buying power, consume. The foregoing statement is amply demonstrated by the fact, emphasized by Mr. Dahlberg, that during the war the workers lived as well as ever before or since, and produced, in addition to all that they consumed, all the materials supplied to our army and all that we shipped to European countries. The real reason why the workers were able to maintain as high a living standard as they were is that they were working full time, although it took six days' pay to buy the production of three days. The spread between the production cost and consumers' price was as great as ever.

During the so-called prosperous years from 1923 to 1929, while interest and dividends increased 140 per cent, there was a decrease in the ratio of consumption to production of the workers.[4] Real payrolls (manufacturing) decreased from

[2] See MECHANICAL ENGINEERING, March, 1933, pp. 157–161.

[3] Mem. A.S.M.E.

[4] See Taylor Society *Bulletin*, October, 1932, Tables 9 and 10 on p. 181.

107.4 in 1923 to 103.4 in 1929, while physical production increased from 100 in 1923 to 117.8 in 1929. The ratio 107.4/100 = 1.074 in 1923 became 103.4/117.8 = 0.879 in 1929, a reduction of 18.1 per cent. Surely there was an increasing lack of consumer purchasing power during these "prosperous" years when the worker, who represents not only the largest but the most important part of the population, can buy and consume a decreasing part of his production. The workers' living standard should at least increase as fast as his production.

Professor Slichter admits that too much investment in the industries producing consumers' goods will cause maladjustments, but he says we then should put the extra capital into industries making capital goods. This means that after we had built up the production capacity of automobiles to three times the average consumption, we should then build up the capacity to build machine tools in the same way. It would seem to a layman, after reading Mr. Rastall's paper in MECHANICAL ENGINEERING for January, 1933, that we did exactly this. There is a very thin distinction between investment in production equipment to produce consumers' goods and in capacity to produce capital goods. The lack of demand for the one follows closely the lack of demand for the other.

Professor Slichter states: ". . . the essential trouble is not that the distribution of incomes is too unequal and that savings increase too rapidly relative to consumer purchasing power, but rather that mistakes are made in investing savings so that the equipment of industry does not adjust itself properly to changes in demand produced by changes in the distribution of income." The foregoing suggests that we invest more of the savings in equipment to produce goods for the high-income group. In 1929 there were 1,400,000 incomes over $5000. The market for mass-production goods requiring capital investment is the 98 per cent with low incomes, not the 2 per cent with high incomes.

I read the other day that "Savings = debts + hoarding." Debts created by the building of needed and used production plants are socially desirable as the plants are necessary for economical production and they create an opportunity for financing old-age incomes, insurance, etc. Debts created by overbuilding production capacity or for unneeded public works are socially undesirable, as they create a drain on future buying power with no compensating benefits. We must admit that savings from 1923 to 1929 were much greater than the social need demanded and were to a large extent wasted.

If much of the money saved had been put into workers' payrolls, where 96 per cent of it would have been promptly spent for consumers' goods and housing, the economic balance would have been maintained much better than it was. A more important result is that the living standard, health, and happiness of the people would have been increased. Technological unemployment (except for temporary readjustments) is caused by technological cost reduction with no corresponding price reduction. Technological cost reduction with corresponding price reductions will increase volume and employment, give a higher living standard, and, ultimately, leisure. Leisure is time voluntarily spent without work when fairly paid work is at hand. "Lack of consumer purchasing power" is still a contender for the honor of having caused the depression.

I agree with the arguments advanced by Professor Slichter that credits have been responsible for many of our maladjustments, but credits are debts and debts are a result of savings, so if savings are limited to actual needs, credit evils also will be limited.

We must have a social control of the spread between the production cost and selling price of goods so that the percentage of the receipts from the sale of goods going into pay envelopes will be increased. The purpose and guide of this social control would be to obtain an ever-increasing ratio of total productive payrolls to total receipts from the sale of goods. Capital earnings, in percentages, would be limited by this control, but the resulting high-volume production would ultimately give high-capital earnings in dollars. A method of obtaining this social control was presented by the writer before the December, 1932, meeting of The Taylor Society.

J. E. WEBSTER.[5]

East Pittsburgh, Pa.

TO THE EDITOR:

Mr. Webster's comments on my paper reflect an interpretation of cyclical phenomena which is very prevalent and yet with which I can only partly agree. To be sure, there is much evidence that, among the many maladjustments which precipitated the present depression, was the overdevelopment of some consumer-goods industries relative to consumer purchasing power. Indeed, as I said in my paper (p. 97): "I believe that this result happens during practically every boom." These superficial facts, however, should not lead us to misinterpret the real nature of the difficulty. It does not follow that the volume of consumer income was too small and that savings or investments, or both, were too large. Rather it follows that investment failed to adjust itself properly to the demand for goods, that too little went into capital-goods industries and too much into consumer-goods industries. This meant unemployment and, of course, a drop in consumer-purchasing power—the inadequacy of which is simply a consequence of the failure of investment to keep properly adjusted to the demand for goods. In other words, mere changes in the distribution of wealth and in the volume of saving are not alone sufficient to account for depressions. They do so only when there is maladjustment between the kind of goods which industry is equipped to produce and the kind of goods which the community demands.

These exceedingly general statements do not, of course, adequately indicate the problems and difficulties that are involved in keeping demand and producing capacity in adjustment in a growing industrial society. Changes in the rate of growth require changes in the demand for goods, and changes in the demand for goods require changes in the rate of industrial growth. It has been suggested that the stability of our economic system might be increased by reducing the volume of investment spending to all spending. It is true that investment is the most difficult kind of spending to do and that mistakes in investment are peculiarly easy to make. In fact, in view of our limited ability to forecast demand, it is impossible entirely to avoid making them. For this reason, as I pointed out, if investment spending were a smaller part of total spending, maladjustments within industry would develop more slowly, and breakdowns in exchange would occur less frequently. But they would come sooner or later, as long as mistakes in investing were made, and it would take a substantial drop in the volume of investment (and hence probably a drastic drop in the rate of industrial growth) to produce much effect upon business cycles. It follows that the real problem is the proper guidance of investment.

Let me take advantage of this opportunity to direct attention

[5] General Works Engineer, Westinghouse Elec. & Mfg. Co. Mem. A.S.M.E.

to a common misuse of the figures of payrolls in manufacturing Mr. Webster and many others have used these figures as a basis for concluding that consumer purchasing power failed to increase with sufficient rapidity between 1923 and 1929. It happens that wage earners employed in manufacturing constitute little more than one-fourth of all gainfully employed persons. Furthermore, the decade of the twenties was a period in which employment was practically stationary in manufacturing but increasing in most other branches of industry.

Figures which make satisfactory allowance for the volume of unemployment in 1930 are not available, but the census of occupations shows large gains over 1920 in practically all occupational groups except agriculture, mining, and manufacturing; 44.9 per cent in transportation, 77.6 per cent in trade, 37.3 per cent in public service, 59.8 per cent in professional service, 4.3 per cent in domestic and personal service, groups which together contain half again more workers than manufacturing. The increase in the total gainfully employed was 17.3 per cent. Whatever may be the facts in regard to the trend in consumers' purchasing power, payroll disbursements in manufacturing cannot be accepted as a satisfactory sample.

Finally, let me observe that attempts to explain business cycles simply through changes in the distribution of wealth and in the volume of consumer purchasing power conceive the problem in too narrow terms. They overlook the multitude of influences which in an uncertain and changing world play upon the total volume of spending, which cause commitments to be deferred and kept as small as possible at some times and to be hastened and made as large as possible at other times. These variations in the total volume of spending are the essence of business cycles. Although cause and effect run both ways and seem to differ somewhat in different cycles, the evidence appears to indicate that, in the main, variations in business spending produce variations in consumer spending, rather than vice versa.

SUMNER H. SLICHTER.[6]

Cambridge, Mass.

How to Pronounce Enthalpy

TO THE EDITOR:

Does a ruling on the pronunciation of rather new technical words fall properly within the activities of the A.S.A.? Or how shall we decide such matters?

Our present system of waiting a few years and then determining pronunciation by "good usage" has its faults in so far as engineering terminology is concerned. One trouble is delay; another is lack of thoughtful guidance. We have plenty of examples of poorly selected names, units, and symbols which have come into such widespread use as to make improvements very difficult, and it is equally possible for unfortunate pronunciations to develop when allowed to grow up unregulated.

An opportunity for early control appears today in the pronunciation of *enthalpy*, a word of considerable utility in thermodynamics but one which does not yet appear in dictionaries. In the printed form it has rather wide currency. At least two recent textbooks on engineering thermodynamics use it repeatedly; it appears frequently in MECHANICAL ENGINEERING; and many of the present generation of engineering students will be familiar with its spelling and meaning. Doubtless these students will follow their teacher's pronunciation. But what pronunciation should the teacher use?

He might follow the pronunciation of the root word, which in this case would put the accent on the second syllable. But doing so violates a strong tendency of the English language to accent the first syllable of words beinning in *en*, such as *energy* and *entropy*. The word entropy itself, once new but now so common in thermodynamics discussions, furnishes an exactly parallel case to enthalpy. For both words, the emphasis in the original Greek would be on the second syllable, but for entropy the English emphasis is definitely on the first syllable. For enthalpy, there are strong precedents for accenting the first syllable, and two publishers of dictionaries have guardedly predicted that ultimately the preferred accent will be placed there.

On the other hand, we are not yet forced to follow such precedent; and having enthalpy pronounced differently from entropy can undoubtedly prevent confusion in spoken discussion. This practical advantage will probably appeal as strongly to engineering professors as to any one, and unless objections to this practice appear, the teachers' example may easily result in a special pronunciation running counter to the general practice for words of that type.

Whoever has an interest in the pronunciation of this word should realize that although its pronunciation is still under our control, if he wishes to help guide good usage into a practice shape, now is the time. Errors in pronunciation are admittedly of rather small practical importance; nevertheless, some of us find the situation uncomfortable and are hoping the men having use for the word will give us a prompt as well as a logical determination of good usage for it.

J. H. POUND.[7]

Houston, Texas.

[Professor Pound's letter was submitted to a number of engineers who are known to have an interest in the use of the word enthalpy and to two publishers of dictionaries. Opinions of the engineers appear to be in favor of accenting the second syllable as advocated by Professor Pound. Both dictionaries agree that the accent *should* be on the second syllable and indicate that it will be so recorded by them if this usage becomes established. It is their function, as every one recognizes, to record established majority usage. As few persons other than engineers use the word, a determination by them to accent the second syllable should rather effectively establish this usage.—EDITOR.]

Training the Engineer to Think

TO THE EDITOR:

I am in complete agreement with much of Mr. Comstock's letter in the June issue of MECHANICAL ENGINEERING, but I do not obtain the same reactions from reading Professor Doherty's paper in the February issue.

My own experience in industry and teaching indicates the necessity for some store of facts and formulas for engineering graduates; but it has convinced me that this end of education is often overdone, with detriment to the graduate. The ability to think must be strengthened without too much emphasis on the vehicle. Professor Doherty has been careful to avoid going into too much detail about course or method.

[6] Professor of Business Economics, Harvard University.

[7] Professor of Mechanical Engineering, Rice Institute. Mem. A.S.M.E.

I am also in accord with Mr. Comstock's statements regarding undue professional pride. We have no just grounds for believing that we engineers are superior to the members of other professions or that we are more capable of solving the world's problems. I have been quite nettled to hear and read such silly claims made by leaders of other professions with respect to members thereof. The awakened interest of both mature engineers and engineering students in those fields of knowledge having close relationship to engineering, such as the social sciences, does not necessarily indicate a belief in their superior ability in those fields. Such interest should go far to help them to better fulfil their own functions in research, design, and construction.

I am pleased to note the trend from too much specialization to more generalization in engineering education. To those of us who early believed in the wisdom of such a move, present conditions have given a better opportunity to convince. As Professor Doherty indicates, one limit is the total amount of time available for one's education.

CARROLL D. BILLMYER.[8]

Kingston, R. I.

Recent Steam Research in Europe

TO THE EDITOR:

Dr. Havliček has called my attention to an error in the curve representing his experimental values for specific heat that appeared as Fig. 7 of my paper in the March issue of MECHANICAL ENGINEERING. The agreement between the Havliček measurements and those by Koch is far better than my Fig. 7 indicated. The corrected diagram will more nearly do justice to their very creditable work in a region so strewn with difficulties.

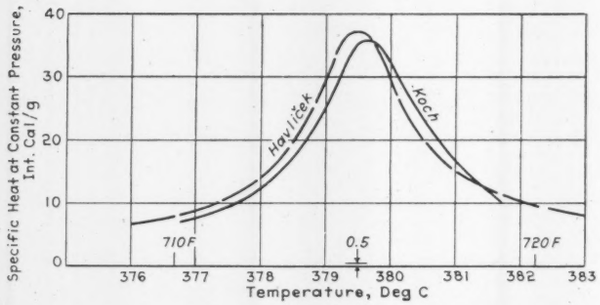

FIG. 7 KOCH AND HAVLICEK SPECIFIC HEATS AT 240 KG PER SQ CM (3413 LB PER SQ IN.)

(A value of 0.5, an approximation to the Regnault value for superheated steam, is shown for comparison.)

My error arose from cross-plotting one of Dr. Havliček's diagrams which was on so small a scale that slight departures from fairness seemed to indicate a lower peak value. If I had made a more painstaking investigation of the trend of his maximum values, I should have found the higher peak shown here.

JOSEPH H. KEENAN.[9]

Hoboken, N. J.

[8] Supt. of Construction and Asst. Prof., Engrg., Rhode Island State College. Mem. A.S.M.E.

[9] Assistant Professor of Mechanical Engineering, Stevens Institute of Technology. Mem. A.S.M.E.

BOOK REVIEWS

Industrial Psychology

TEN YEARS OF INDUSTRIAL PSYCHOLOGY, an Account of the First Decade of the National Institute of Industrial Psychology. By Henry J. Welch and Charles S. Myers. Isaac Pitman & Sons, New York, 1932. Cloth, 5½ × 8¾ in., 146 pp., illus., $2.

REVIEWED BY LILLIAN M. GILBRETH[1]

THIS interestingly written and well-printed book gives an account of the development of industrial psychology in Great Britain which centers about the work of the Institute, which it describes in detail, and also presents the activities of all sorts in this field. This is possible, because these activities are carefully coordinated throughout the empire, so that there is no duplication but real cooperation and a unified body of findings.

Industrial psychology is defined as "the promotion and application of relevant psychological and physiological knowledge to the problems of industry and commerce," and the very phrasing indicates the success attained in correlating various groups and interests to a unified attack on the human-element problem. This is a thing to be envied and studied by any country.

The material presented covers the origin, history, and work of the Institute, and is set up in such a way as to win support, financial and other, for its work, which needs adequate endowment.

The most useful work done seems to be in the field of selection and vocational guidance, though in the final analysis this work must depend on accurate job analysis and motion and time study resulting in better work methods. These, we believe, are the appropriate work of the engineer who has been trained in psychology, rather than of the psychologist, with some experience in the plant, office, or department store. There is a fundamental disagreement between workers in the field of industrial betterment in Europe and in this country, based undoubtedly in part on the training given for the professions of engineering and psychology, which this book makes very clear.

From the standpoint of the American engineer, there is much lacking in appreciation of work done in this country and correlation of that work with the activities in Great Britain. We look for a more detailed evaluation of scientific management and the work of the engineer, in eliminating waste, but especially human waste, and find little, even in a careful reading of this book, to show that there has been any attempt to do more than adopt or adapt our philosophy and technics, with little credit and less accuracy. The book may win adherents and contributors to the Institute abroad, but is not likely to in this country. But it will be read with interest as a clear exposition of a point of view, and will strengthen one's feeling that a world clearing house for management is a vital necessity.

[1] President, Gilbreth, Inc., Consulting Engineer, Montclair, N. J. Mem. A.S.M.E.

INDUSTRIAL PSYCHOLOGY IN PRACTICE. By Henry J. Welch and George H. Miles. Isaac Pitman & Sons, New York, 1932. Cloth, $5^1/_2 \times 8^1/_4$ in., 249 pp., illus., $2.50.

REVIEWED BY LILLIAN M. GILBRETH[1]

THIS book appears to be a complementary volume to the one just reviewed. It discusses in popular form problems concerning the health of the worker and improvement of working conditions and of personnel. The material is excellently presented, and no one can read it without receiving valuable hints on betterment of conditions or work methods that affect the human element. It should prove useful throughout British industry and business.

Unfortunately, it has two faults. In the first place it does not give adequate credit to the sources in the United States from which much of its material is obtained, and in the second place this makes even more serious the fact that the source material has often been inadequately and inaccurately used. This is specifically true of the material which has to do with motion study. Fatigue study is as yet excusable, internationally, for being as unscientific as it is everywhere, because adequate definition, and units, methods, and devices for measuring fatigue are as yet lacking. But motion study does possess these indispensable prerequisites for scientific investigation, and it would seem to be entitled to recognition of this fact.

An American reader of this book may well admire the unity of approach, the wealth of illustrative material, and the simplicity and clearness of the presentation. But for direction in his own work, he will turn to texts which recognize the engineer's demand for technics of measurement. This book does demonstrate what the authors state they hope it will, in their concluding paragraph, where they say that "in industry and commerce there are innumerable points at which a knowledge of psychology will assist in solving human problems"—but it remains to be said that this knowledge should be supplemented by knowledge and use of the material which the engineer has contributed to the betterment of work methods.

Shorter Hours

A STUDY OF THE MOVEMENT SINCE THE CIVIL WAR. By Marion Cotter Cahill. Columbia University Press, New York, 1932. Cloth, $6 \times 8^3/_4$ in., 300 pp., $4.50.

REVIEWED BY H. R. TAUBE[2]

THE failure of measures so far applied to reduce unemployment caused by the present economic calamity—public works, the share-the-work plan, rehabilitation of industry—is convincing proof of the impossibility of remedying a deep-seated social evil by means of improvised expedients. It is becoming increasingly evident that a solution of the problem can be found only in a change of industrial methods and habits tending to adapt them to a changing world. One such change promising reasonable success in the control of unemployment would be a shortening of working time. A limitation of hours to thirty a week, as provided by a bill introduced by Senator Black of Alabama, would presumably make self-supporting a large number—William Green, president of the American Federation of Labor, estimates it at 6,600,000—of the approximately 12 million unemployed.

The Senate hearings held in connection with this bill have attracted general attention to the regulation by law of working hours, and Dr. Cahill's timely book is therefore of particular interest, as it gives a very readable and unbiased historical survey of the way by which, and to what extent, working hours have been shortened in this country since the Civil War.

The author points out that despite the long drawn-out controversy on this subject, we do not possess today any more reliable scientific data concerning the effect of hours upon the health of the workers, on industrial output, and on the relationship between production and consumption than we had thirty years ago. Because of the lack of conclusive data, "the question has not advanced from the plane of opinion, prejudice, and self-interest to that of verifiable fact." The direct means available for a reduction of hours are, in Dr. Cahill's opinion, legislative action, action by organized labor, and action initiated by employers. He finds that the application of these three methods has been simultaneous with the marked influence of changing economic and social conditions, though it might be difficult to trace the effect and scope of these influences in detail.

Since 1866, when the National Labor Union was founded to press the adoption of the eight-hour day, the motives for the demand for shorter hours by organized labor have been the desire for more leisure and the fear of unemployment. The latter of these has become predominant in proportion as the productivity of labor has been increasing due to technological progress. At the same time, the employers' hostility to this demand has been the fear of higher production costs and reduced profits. All the varying phases of the struggle for shorter hours center around these two irreconcilable viewpoints, though the arguments advanced by employers and labor in defense of their interests have, more often than not, tended to becloud the issue.

In the post-Civil War period, reliance was placed upon the legislative method, both nationally and in the individual states. A serious obstacle to far-reaching Federal legislation on conditions of labor is the constitutional limitation of the power of Congress to pass it, and amendments to set aside this limitation has therefore repeatedly been proposed. It was, however, due to the action of labor that Congress, in 1868, enacted an eight-hour law for employees in Federal work. This law proved to be defective and its enforcement so inadequate that it had to be superseded by new laws passed in 1892 and 1912, respectively. Other Federal laws regulate now the work day of railroad employees and seamen.

The enactment of state laws was greatly hampered by court decisions to the effect that hours legislation was an unjustifiable interference with the freedom of contract. A turning point in this situation was a decision of the United States Supreme Court, delivered in 1908, sustaining the constitutionality of the ten-hour day for women passed by the legislature of Oregon. Nevertheless, further progress in the individual states cannot be expected because the lack of uniformity would place the states with progressive labor legislation at a competitive disadvantage with states having none. As a second reason for the slow progress in state action, Dr. Cahill gives "the active hostility of the American Federation of Labor toward general hours legislation which is in strong contrast to its leadership in efforts to have hour laws enacted for women, for workers in state and city jobs, and for hazardous industries." The author discusses at length the attitude of organized labor, and in particular of the American Federation of Labor, to the hours question, and characterizes the policy of the latter as one of "uncertainty and lack of leadership."

Concerning voluntary reduction of hours by employers, the author finds that such action has been less common than that brought about by legislation and labor. But, "while such a conscious policy has not been common in the past and indications do not warrant the assumption that it will be in the near future, it should be remembered that general condi-

[2] New York. Mem. A.S.M.E.

tions have played a part in the spread of the reduction of hours and will continue to do so."

Compared with the enormous strides made in the productivity of labor, the result of the movement for shorter hours is anything but impressive. The number of full-time hours per week was 58.4 in 1890, and it dropped to 51.3 in 1899, and to 49.6 in 1927, being estimated today at 41.6. In other words, the reduction of hours per week between 1899 and 1927 was only 3.3 per cent, while the productivity of labor increased in the same period about 43 per cent. In many industries the average weekly hours were much higher, for instance, 60.8 in the Portland-cement industry and 58.7 in cane-sugar refining.

In summing up, the author comes to the somewhat pessimistic conclusion that "unless an unforeseeable change occurs, there is every prospect that history will repeat itself, and that the period to come will be a steady, dogged, frequently hopeless insistence by one great part of society on the need for shorter hours, which will bring about a further but gradual reduction through a combination of legislative, direct, and voluntary action." This view disregards the important fact that the question of working conditions in general, and hours in particular, has ceased to be a matter of concern to employers and labor only, but has become an issue of public policy in which all strata of society are vitally interested. Intelligent public opinion has become aware of the fact that the technological progress of the last three decades has made it possible to produce all requirements with a steadily decreasing number of man-hours, and rightly or wrongly the belief is spreading that shorter hours offer a sound method to put more men to work. With an aroused public opinion in favor of certain industrial reforms, among them a shorter working week, it can be only a question of time that ways and means will be found to overcome legalistic obstacles to their enactment and enforcement.

The American Year Book

THE AMERICAN YEAR BOOK—A Record of Events and Progress for the Year 1932. Edited by Albert Bushnell Hart and William M. Schuyler. The American Year Book Corporation, New York, 1933. Cloth, 5 × 8 in., 947 pp., net $7.50

THE American Year Book, the publication of which has been made possible by the generosity of The New York *Times* and its president, Mr. Adolph S. Ochs, is a review of progress for the year. Engineers will be particularly interested in Division 19, Engineering and Construction. The very fact that in such a review some 70 pages are devoted directly to engineering and another 50 pages to cognate subjects, is an indication of the importance of the engineering profession in the light of all other activities of the nation. Division 19 comprises articles on structural engineering, mechanical engineering, electrical engineering, automotive engineering, naval architecture and marine engineering, commercial marine engineering, materials of engineering and construction, industrial standardization, commercial aviation, and American machinery generally.

Engineers will be interested also in the chapters on chemistry and physics, Division 21, covering inorganic and physical chemistry, organic and agricultural chemistry, electrochemistry, chemical engineering, and physics.

Articles on the motor-bus industry and community transit involve numerous engineering features and so does the article on progress in aeronautics and the radio.

In the articles devoted to engineering subjects primarily, the tendency is to present not only an account of the strictly technical developments, but to touch upon their social implications, and, at times, their commercial value.

Engineers may not yet have reached the stage where the leadership of the nation should be formally entrusted to them, and may never reach it. A survey of such a book as The American Year Book, however, shows how, at least in this country, engineering developments are more and more becoming that basic background against which social and economic changes are developing.—L. C.

Books Received in the Library

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS GUIDE, 1933, Vol. 11. American Society of Heating and Ventilating Engineers, New York. Leather, 6 × 9 in., 765 pp., illus., diagrams, charts, tables, $5. The new edition of this well-known reference book is patterned upon previous ones, but the text has been thoroughly revised. New information on transmission losses, heating boilers, ventilation and air conditioning has been incorporated. In addition to the technical data, the book includes catalog data from manufacturers and the membership roll of the Society.

ATOM AND COSMOS, the World of Modern Physics. By H. Reichenbach; translated and revised by E. S. Allen. Macmillan Co., New York, 1933. Cloth, 6 × 8 in., 300 pp., illus., diagrams, $2. Dr. Reichenbach's purpose is to explain the significance to modern life and thought of recent discoveries in physics. The accomplishments of the major physicists of the day are analyzed, and the new theories of space, time, light, radiation, matter and electricity are presented. The claims and counter-claims of various scientists are balanced, the insufficiency of old concepts is shown, and the new concepts indicated are discussed. The work is founded upon lectures broadcast from Berlin, and is intended for laymen.

L'ÉCOULEMENT EN CONDUITES DES LIQUIDES, GAZ ET VAPEURS. By A. Schlag. Dunod, Paris, 1933. Paper, 5 × 8 in., 182 pp., diagrams, charts, tables, paper, 18 frs. Current formulas for determining the flow of fluids are presented, with a concise description of the theories and experimental data upon which they are based. A bibliography is included.

ENGINEERING SHOP PRACTICE, Vol. 1. By O. W. Boston. John Wiley & Sons, New York, 1933. Cloth, 6 × 9 in., 539 pp., illus., diagrams, charts, tables, $5.50. A textbook intended to familiarize students with the materials and engineering principles used in manufacture. This volume discusses the machine-shop and the basic machining processes, such as lathe work, planing, shaping, milling, sawing and drilling, and is to be followed by a second. While primarily intended for class use, it will also be a convenient reference book for information upon modern machine tools, typical machining operations, and recent investigations of metal cutting.

FAHRZEUGBAU. (Ausgewählte Schweisskonstruktionen, Vol. 4.) By E. Kalisch. V.D.I. Verlag, Berlin, 1933. Cloth, 8 × 12 in. 90 pp., illus., diagrams, cloth ($3, G. E. Stechert). An atlas of photographs and drawings, selected by the Welding Section of the Society of German Engineers, to illustrate welding methods used in German factories. The methods given refer to the manufacture of railroad cars, locomotives, airplanes, automobiles, and trucks. Ninety plates, showing over two hundred uses, are given.

FRIEDRICH KOENIG. (Deutsches Museum Abhandlungen und Berichte, Vol. 5, No. 1.) By A. Bolza. V.D.I. Verlag, Berlin, 1933. Paper, 6 × 8 in., 30 pp., illus., 0.90 rm. In commemoration of the centenary of the death of the inventor of the cylinder printing press, on January 17, the Deutsches Museum has issued this brief account of his life and work.

GREAT DELUSION, Some Facts About Government in Business. By E. Greenwood. Harper & Brothers, New York and London, 1933. Cloth, 5 × 8 in., 238 pp., $2.50. This work discusses the relation of government to business and to the regulation of business. The author is alarmed at the gradual intrusion of government into business which is occurring and by its efforts to regulate or compete with private initiative. He presents the case against government ownership forcibly and readably. His illustrations are drawn chiefly from the electric power industry.

HOW TO RESTORE VALUES; The Quick, Safe Way Out of the Depression. By Ambrose W. Benkert, in collaboration with Earl Harding. John Day Company, Inc., New York, 1933. Pamphlet No. 23, $5\frac{1}{4} \times 7\frac{3}{4}$

in., 32 pp., $0.25. For 25 cents and less than an hour's reading one can obtain a clearly sketched picture of some of the principal factors behind the fall of world prices and the maladjustment of the relationship of the prices of flexible and inflexible items that make up goods and services. Two methods of procedure in the restoration of price equilibrium are briefly analyzed; the natural process of deflation, and the raising of the price level of the flexible items which are determined by a free market to parity with that of the inflexible item. The way out, after a discussion of many schemes put forward by proponents of both methods, is, according to the authors, currency deflation, which is to be accomplished by a managed currency based upon the United States Bureau of Labor's price index.—G. A. S.

HYDRAULIC MACHINERY. By D. W. Mead. McGraw-Hill Book Co., New York and London, 1933. Cloth, 6 × 10 in., 396 pp., illus., diagrams, charts, tables, $4. The first third of this book deals with the general principles of hydraulic machinery and with methods of generating and using power in general. It includes a method of plant analysis by which alternative methods of power generation and utilization can be compared and the best selected. The remainder of the volume discusses pumping machinery, with special attention to small installations. As few engineers are called upon to design hydraulic machinery, compared to those who from time to time must select, install or operate it, the book is written from the viewpoint of the purchaser. Prepared primarily for students, but useful generally as a practical discussion on broad lines.

HYDRODYNAMICS. By Sir H. Lamb. Sixth edition. University Press, Cambridge (England); Macmillan Co., New York, 1932. Cloth, 7 × 11 in., 738 pp., diagrams, tables, $12. Professor Lamb's classic treatise has been for so many years an accepted authority that little is needed except the announcement of the new edition. It is unchanged in plan and arrangement but has been revised throughout and includes much new matter. Developments of recent years have been indicated.

INDUSTRIAL ELECTRIC HEATING. By N. R. Stansel. John Wiley & Sons, New York, 1933. Cloth, 6 × 9 in., 444 pp., illus., diagrams, charts, tables, $5. This volume presents, in revised and slightly enlarged form, a series of articles which appeared in the *General Electric Review*. The author first reviews briefly the more important principles of thermal engineering. This is followed by a discussion of the construction of the various types of electric furnaces and of their uses, with examples of their application. Low-temperature heating, induction heating of solids, the production of ferro-alloys and some other phases of heating are not included.

IRON AND STEEL (a pocket encyclopedia). By H. P. Tiemann. Third edition. McGraw-Hill Book Co., New York and London, 1933. Leather, 4 × 7 in., 590 pp., illus., diagrams, tables, $4. This work can be warmly recommended to every one concerned with the fabrication, sale, or use of iron or steel as an exceptionally useful reference book. Under an alphabetical arrangement, it provides definitions and brief, clear descriptions of the processes and methods of the industry, of the technical terms used and of terms related to allied sciences, fulfilling the purposes of a dictionary and an encyclopedia. The new edition has been carefully revised.

JAHRBUCH DER BRENNKRAFTTECHNISCHEN GESELLSCHAFT E. V. Vols. 9–12, 1928–1931. Wilhelm Knapp, Halle (Saale), 1932. Paper, 8 × 11 in., illus., diagrams, charts, tables, vol. 9, 68 pp., 6.75 rm.; vol. 10, 38 pp., 4.85 rm.; vol. 11, 51 pp., 5.85 rm.; vol. 12, 96 pp., 10 rm. These volumes contain the papers and discussions presented at the annual meetings of the Combustion Engineering Society. Among the topics discussed are the standardization of Diesel-engine fuels, the problem of materials for marine Diesel engines, the production of fuels from coal, combustion-engine lubrication and lubricants, and the chemical utilization of coke-oven gas. The topics treated have value on many phases of fuel engineering.

JAHRBUCH 1932 DER DEUTSCHEN VERSUCHSANSTALT FÜR LUFTFAHRT, E.V., Berlin-Adlershof. Edited by W. Hoff. R. Oldenbourg, Munich and Berlin, 1932. Cloth, 8 × 12 in., 518 pp., illus., diagrams, charts, tables, 35 rm. The first section of the Yearbook describes the work of the German Experimental Institute for Aviation and gives brief abstracts of some two hundred papers, mostly unpublished as yet. The second section contains 53 papers of importance. Among these are reports upon flight tests for the measurement of polar curve and influence of slip stream; the German investigation of the Meopham accident; investigations of landing-wheel tires; aircraft engine construction; light alloys; blind landing; and lateral stability. The volume provides a great collection of experimental data upon all phases of aviation.

NEW FRONTIERS OF PHYSICS. By P. R. Heyl. D. Appleton, New York and London, 1930. Cloth, 5 × 8 in., 170 pp., illus., diagrams, $2. Dr. Heyl gives an account of recent developments in physics and of the new concepts that have revolutionized that subject in recent years. The book is intended for the general reader without special scientific training, who will find it very satisfactory.

NUMEROLOGY. By E. T. Bell. Williams & Wilkins Co., Baltimore, 1933. Cloth, 5 × 8 in., 187 pp., diagrams, $2. "My jaunt into numerology," says the author, "was undertaken to answer the question, is there more science in numerology than there is numerology in science?" In satiric mood, he unravels some of the mysteries of number and traces the history of numerology, ancient and modern. Dr. Bell is professor of mathematics in the California Institute of Technology.

PRINCIPLES OF INDUSTRIAL MANAGEMENT. By E. A. Allcut. Isaac Pitman & Sons, London, Toronto, and New York, 1932. Leather, 6 × 9 in., 218 pp., illus., diagrams, charts, tables, $3. A textbook for students giving a good, concise presentation of principles, without attempting to describe the details of industrial administration. While primarily for students, others desirous of some general knowledge of the subject will find it useful.

PROBLEMS IN PUBLIC UTILITY ECONOMICS AND MANAGEMENT. By C. O. Ruggles. McGraw-Hill Book Co., New York and London, 1933. Cloth, 6 × 9 in., 737 pp., charts, tables, $6. The case method is here applied to the analysis and solution of problems dealing with economic and business aspects of public utilities. One hundred and twenty problems, based on actual cases, are discussed. They cover problems of production, management, wholesale and retail marketing, valuation, rate making, regulation, etc.

PUBLIC UTILITY REGULATION. By W. E. Mosher and F. G. Crawford. Harper & Brothers, New York and London, 1933. Cloth, 6 × 9 in., 612 pp., tables, $5. This book is a study of the scope and effectiveness of present methods of regulating public utilities through public service commissions. Stress is laid on administrative aspects of regulation rather than legal and economic ones, although these are also considered. Ways in which present powers and methods might be made more effective are indicated.

RECENT SOCIAL TRENDS IN THE UNITED STATES, Report of the President's Research Committee on Social Trends, with a foreword by Herbert Hoover. Two vols. McGraw-Hill Book Co., New York and London, 1933. Cloth, 6 × 10 in., 1568 pp., diagrams, charts, tables, $10. The results of the comprehensive survey of American institutions and activities which has been in progress since 1929 are summarized in these volumes, which bring together in a unified whole an enormous mass of facts about our life and social problems. The problems arising from our physical, biological, and social heritages are discussed in twenty-nine reports by various specialists, to which is added a preliminary report which gives an interrelated view of the whole. Every main division is covered with a wealth of data, of value to economists, business men, industrialists, and officials.

TABLES ANNUELLES DE CONSTANTES ET DONNÉES NUMÉRIQUES de Chimie, de Physique, de Biologie et de Technologie. TABLES DES MATIÈRES, vol. 9, 1929. Gauthier-Villars et Cie, Paris; McGraw-Hill Book Co., New York, 1932. Paper, 9 × 11 in., 124 pp., free to purchasers of vol. 9. This index completes the 1929 volume of the Annual Tables of Constants and will be needed by all users of that work. An alphabetic index and an index of formulas are provided.

VECTOR ANALYSIS. By H. B. Phillips. John Wiley & Sons, New York, 1933. Cloth, 6 × 9 in., 236 pp., diagrams, tables, $2.50. This book presents the subject in the form required for work in theoretical electricity and hydrodynamics. The fundamental operations and more general properties of scalar and vector fields are presented, after which the detailed analysis of fields, the properties of potentials, and linear vector functions are discussed.

WHAT IS TECHNOCRACY? By A. Raymond. McGraw-Hill Book Co., New York and London (Whittlesey House) 1933. Cloth, 5 × 8 in., 180 pp., tables, $1.50. This volume gives the theories of technocracy as the leaders of the movement have described it, discusses the careers and personalities of these leaders, and studies the sources from which its theories have been developed. The criticisms which have appeared are discussed and, finally, the author's appraisal of the movement is given. The book is based upon an investigation made for the *New York Herald-Tribune*, and is, in a sense, an expansion of articles published in that newspaper.

WHAT'S GOING ON

Oil and Gas Power Meeting at Atlantic City

THE Sixth National Meeting of the Oil and Gas Power Division of The American Society of Mechanical Engineers will be be held at the Ritz-Carlton Hotel, Atlantic City, N. J., August 23 to 26, 1933. The usual exhibit of accessories and Diesel-engine supplies will be held in conjunction with the meeting. The all-expense plan, provided by the committee's arrangements, includes meals from lunch on Wednesday to lunch on Saturday, room, open-air garage, bus to and from hotel, banquet, women's tea, evening card party, and bathing privileges, at a total cost of $20.50 per person on the basis of two in a room.

Aside from technical papers and discussions, the exhibit, the usual recreational opportunities for which Atlantic City is famous, and the special program of social events for the women, the customary Oil and Gas Power Division golf tournament will be held on Friday afternoon on nearby golf links.

Registration for the meeting commences at 10 a.m., Wednesday morning, August 23, with the opening of the exhibit. The first technical session will be held on Wednesday afternoon. On Thursday, Friday, and Saturday, the mornings will be devoted to technical sessions, the afternoons being left free for recreation. On Wednesday evening there will be a get-together dance. The card party will take place on Thursday evening, and on Friday evening a banquet will be held, at which Edward B. Pollister, president of the Busch-Sulzer Bros. Diesel Engine Co., will deliver an address on "Sea Power and the Diesel Engine."

The complete program is given below. Further information as to the exhibits or the program may be obtained by addressing the A.S.M.E. Oil and Gas Power Division, 29 West 39th Street, New York, N. Y.

Wednesday, August 23

10 a.m. Registration

12 to 2 p.m. Luncheon, Dining Room

2:30 p.m. Technical Session, Trellis Room Third Floor

Chairman, Louis R. Ford

Welding of Diesel Frames and Parts, Everett Chapman, Vice-President, Lukenweld, Inc.
Causes and Effects of Pressure Waves in Fuel Injection Systems, Ralph Miller, chief engineer, Oil Engine Department, Ingersoll-Rand Co.

7 p.m. Dinner, Dining Room

8:30p.m. Get-Together and Dance, Grill Room

Thursday, August 24

7:30–9 a.m. Breakfast, Dining Room

9:30 a.m. Technical Session

Chairman, S. E. Nibbs

Reducing the Performance of a Solid-Injection Engine to Standard Conditions, H. A. Everett, Pennsylvania State College
Supercharging of Diesel Engines, Charles G. Curtis

12:30 p.m. Luncheon, Dining Room

2:30 p.m. Committee Meetings

7 p.m. Dinner, Dining Room

8:30 p.m. Card party, Trellis Room

Friday, August 25

7:30–9:30 a.m. Breakfast, Dining Room

9:30 a.m. Technical Session

Chairman, Harte Cooke

Effect of Controlled Turbulence, M. S. Huckle and C. F. Taylor, Massachusetts Institute of Technology
Low-Compression Oil Engines, Frederick Dutcher, Columbia University

12:30 p.m. Luncheon, Dining Room

2:30 p.m. Committee Meetings

8 p.m. Banquet, Trellis Room

Toastmaster, H. Birchard Taylor, President, Diesel Engine Manufacturers Association

Sea Power and the Diesel Engine, E. B. Pollister, President, Busch-Sulzer Bros. Diesel Engine Co.

Saturday, August 26

7:30–9 a.m. Breakfast, Dining Room

9:30 a.m. Technical Session

Chairman, L. M. Goldsmith

Report of the A.S.M.E. Subcommittee on Oil-Engine Power Costs, M. J. Reed
Diesel-Plant Operation, Ralph Troseth

12:30–2 p.m. Luncheon, Dining Room

Engineers' Rights Restored

THE injustice done to the engineering profession several years ago has been rectified by recent legislation in New York State. An amendment was passed restoring to engineers the right to file plans for multiple dwellings. Some building departments had interpreted the old provisions to include industrial buildings, and as a result, many industrial engineers were deprived of their means of livelihood. The architectural profession very generously cooperated with engineers in obtaining the new legislation. Engineers in other states should profit by experience in New York, and keep in touch with laws introduced into their state legislatures so that acts detrimental to the profession may not be passed because of indifference on the part of engineers.

The New York State amendment and three others affecting the practice of engineering in the State of New York were passed in the recent session of the New York State Legislature and became law when they were signed by Governor Lehman.

Senate Bill 1069, amending Section 300 of the Multiple Dwelling Law, was signed by the Governor on April 25 and became Chapter 398 of the Laws of 1933. Through this bill, the right of licensed professional engineers to file plans for multiple dwellings and any other buildings or structures, and alterations thereto, has been completely restored and legally established.

Senate Bill 1771, amending two sections of the engineers' licensing law, was signed by the Governor on April 24 and became Chapter 332 of the Laws of 1933. The purpose of this bill is to safeguard the public by stopping existing evasions of the professional-practice statutes. The amendment to Section 1450 in this bill improves and clarifies the phrasing of the present restriction of the unlicensed use of the professional designations, so as to facilitate interpretation and enforcement. The former phrasing of the statute prevented effective correction of such evasions of the law. The new phrasing which has now been written into the Law fully restricts the use of the professional designation to licensed men so as clearly to protect the designations "engineer" and "surveyor," and not merely the designations "professional engineer" and "land surveyor." With this amendment it will be possible to prosecute those who continue to deceive or mislead the public by calling themselves engineers or surveyors when they are not licensed as professional engineers or land surveyors. This bill also amends Section 1461 of the engineers' licensing law by eliminating an inconsistent exemption permitting unlicensed men to practice land surveying in rural districts.

Senate Bill 1551, covering several amendments to the engineers' licensing law, was signed by the Governor on April 24 and became Chapter 331 of the Laws of 1933. This bill includes an amendment to Section 1450 of the engineers' law, so as to stop present evasions of the law by unlicensed men who report preliminary estimates as under $10,000 for larger buildings and structures which they undertake to design and build without a professional license. The new amendment simply adds a cubic-content specification to the present cost specification, limiting the size of buildings and structures that may be designed by men who are neither licensed engineers nor licensed architects. Section 1452 is amended by raising the minimum definition of "long-established and recognized standing in the engineering profession," for exemption from the examination requirements for licensing, from 12 to 15 years. In addition, the bill eliminates the "grandfather clause" exempting from examination requirements those who were practicing prior to 1916. The bill also includes a complete new section covering disciplinary proceedings so as to improve the effectiveness of this section of the engineers licensing law. The provisions have been amplified so as to permit the Engineers' Board

to recommend revocation, suspension, or annulment of license, or reprimanding, censoring, or otherwise disciplining any licensed engineers found guilty of violating proper professional conduct.

Senate Bill 1084, amending the architects' law, was signed by the Governor on April 24 and became Chapter 333 of the Laws of 1933. This bill makes several amendments to the architects' law parallel to those introduced in the engineers' law.

Lubrication Engineering Meeting

THE Lubrication Engineering Meeting, held under the joint auspices of the A.S.M.E. Lubrication Engineering Committee and Pennsylvania State College, at State College, Pa., on May 25 and 26, provoked a lively discussion of the need for a viscosity classification system for industrial lubricants that resulted in the passing of a motion to ask the Council of The American Society of Mechanical Engineers to petition the American Standards Association to organize a committee to develop a simple, significant, and readily interpretable system.

The technical program was entirely given over to industrial lubrication problems and covered such subjects as lubricant specifications, machine design, roll-neck lubrication, extreme-pressure lubricants, heavy-duty gear lubrication, wire-rope lubrication, and lubrication of large rotating apparatus. The greatest interest centered about the discussion on Thursday evening of need for a viscosity classification system. Dr. A. E. Becker, of the Standard Oil Development Company, opened the discussion and showed that the need of such a classification was evident from the fact that a number of associations, as well as a number of users of lubricants, were attempting to classify lubricants according to viscosity. Dr. Becker, who is Chairman of the Lubrication Committee of the Society of Automotive Engineers, painted a broad picture of the situation on the basis of his extensive experience. He was followed by C. M. Larson, of the Sinclair Refining Company, who endorsed Dr. Becker's suggestion for a practical classification system and analyzed the present need and the possibility of including at some later date a viscosity index and an extreme-pressure symbol in any classification system adopted. The ensuing discussion was exceedingly lively, although every one was favorable to the suggestion of the developing of a classification system. The resulting motion, asking for the establishment of a committee under the procedure of the A.S.A., was passed unanimously.

The Lubrication Engineering Committee of the A.S.M.E. Petroleum Division met at the conclusion of the meeting and decided to appoint two special subcommittees to carry on the work of viscosity classification, pending the appointment of the A.S.A. committee. One of these committees is to be known as a Refinery Viscosity Classification Committee, with Dr. A. E. Becker as chairman, and with three vice-chairmen, representing the Eastern, Mid-Continent, and Pacific Coast sections. Capt. W. C. Thee, of the U. S. Army, was chosen secretary of this committee. This committee's work is to develop further the suggestions made by Dr. Becker and Mr. Larson and to secure from oil refiners their comments and suggestions.

The second committee formed was on Viscosity Needs of Users. The work of this committee will be to secure information on viscosity classifications now being used and on the necessary factors to be included in such classifications. William F. Parish was chosen as chairman of this committee with Harvey Konheim as secretary. Several lubrication engineers, representing such fields as iron and steel, rubber, and machine tools, have already accepted appointments to this committee.

It was decided to limit the work of the two committees, for the present, to viscosity classification numbers.

The Lubrication Engineering Committee also appointed a special committee to function as a clearing house in gathering information on design problems in applying lubricants. C. H. Bromley was appointed chairman of this group.

Engineering News From Washington, D. C.

THE Executive Committee of the American Engineering Council met Tuesday, May 2, in the office of the Executive Secretary, Washington, D. C.

Among the matters considered by the committee was a request of Secretary of Commerce Daniel C. Roper, relative to Senate Resolution 220, 72nd Congress, dealing with detailed estimates of the national income for 1929 and subsequent years. Secretary Roper's request was in parts as follows:

"To comply with the Senate request, it is proving necessary to seek the assistance of a number of non-governmental agencies. Data regarding the income of certain professions are now needed and I should appreciate any assistance that you might be able to give our Division of Economic Research in developing adequate income data concerning the engineering profession."

In compliance with this request, the Executive Secretary was authorized to make such studies as necessary to furnish information to the Secretary of Commerce.

The committee considered a bill, S. 1129, amending the U. S. Code relating to construction and inspection of boilers. The purpose of this bill is to bring the rules and regulations of the Bureau of Navigation and Steamboat Inspection up to date. The framing of the bill represents the combined efforts of the Bureau and the Boiler Code Committee of The American Society of Mechanical Engineers. The committee voted that Council approve and support this legislation.

The committee received and approved the report of Council's Committee on Patents relative to several patent bills which lapsed with the end of the 72nd Congress. The titles of these bills and recommendations of the committee are as follows:

A bill to empower assignee of inventor to file divisional, continuation, renewal, or reissue application. *Voted: to support.*

A bill to limit the life of a patent to a term commencing with the date of the application. *Voted: to disapprove.*

A bill permitting single signature in patent applications and validating joint patent for sole invention. *Voted: to approve.*

A bill to abolish the statute permitting renewal of applications. *Voted: to disapprove.*

A bill to limit inventors to priority of two years before filing applications for patent. *Voted: to approve.*

A bill to provide a permanent force to classify patents, etc., in the Patent Office. *Voted: to approve.*

A bill to prevent fraud, deception, or improper practice in connection with business before the U. S. Patent Office and for other purposes. *Voted: to approve.*

A bill to amend the statute relating to patent disclaimers. *Voted: to disapprove.*

While these bills were not then pending in Congress, it was known that they will be reintroduced. Council's position on this legislation will be governed by the above adopted recommendations.

FEDERAL RESEARCH AND TECHNICAL ACTIVITIES THREATENED

Due to the Administration's determination to reduce drastically the operating costs of the Federal Government for the fiscal year 1934, it has appeared possible that many important Federal services will not have sufficient funds to perform their functions in a manner consistent with the public welfare. This danger is especially imminent in connection with many of the scientific services.

Council has directed its efforts to calling to the attention of those in authority the untortunate results which would follow an indiscriminate reduction of these services without regard to their usefulness. In this connection, the inadvisability of severely curtailing the activities of the Bureau of Agricultural Engineering has been pointed out. The research work of this Bureau is of great value in conjunction with alleviating the present agricultural distress.

Council has also indicated the engineering profession's interest in the activities of the Weather Bureau. It has requested that in arriving at any plans to limit the scope of this Federal agency, careful thought be given to the dependence which engineers place on the data collected by the Bureau.

Daniel C. Jackling Awarded the John Fritz Medal

DANIEL COWAN JACKLING, president of the Utah Copper Company, was presented the John Fritz Medal "for notable industrial achievement in initiating mass production of copper from low-grade ores, through the application of engineering principles," at a dinner held at the Union League Club, New York, N. Y., April 20, 1933.

Frederick M. Becket, president of the A.I.M.E., acted as chairman; and Francis